Environmental CONTAMINATION

from

WEAPON TESTS

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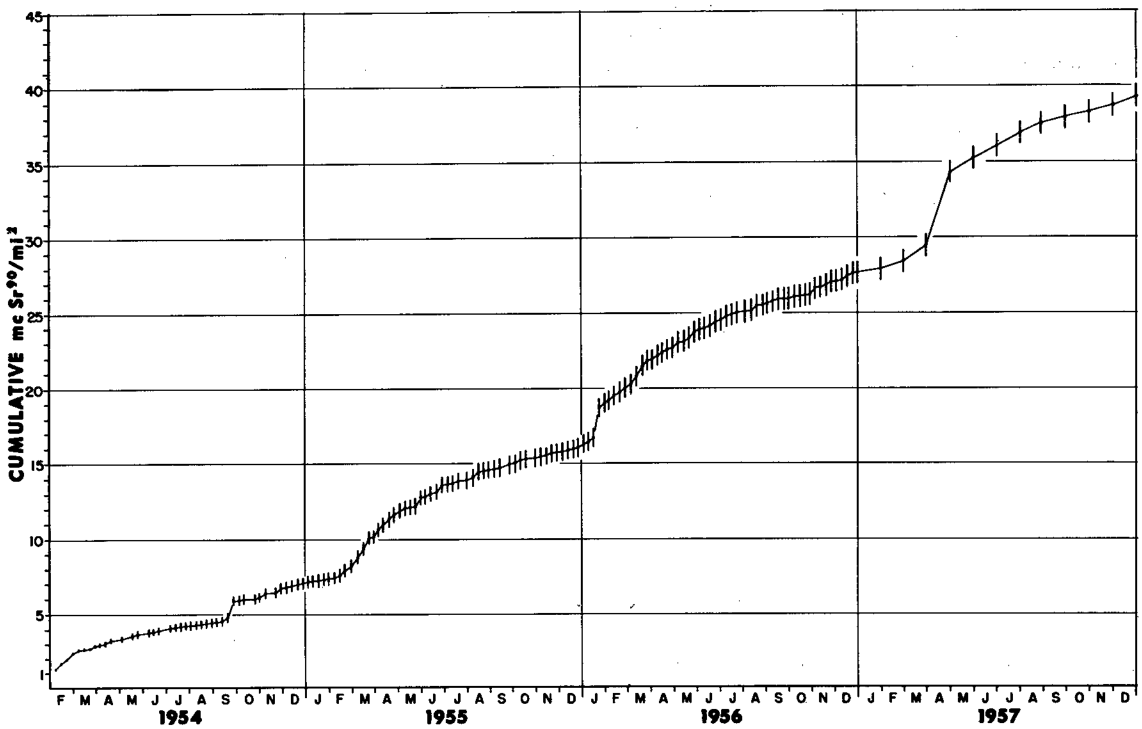

Fig. 1—Sr^{90} in New York City fallout. (High-walled stainless-steel pot collections.)

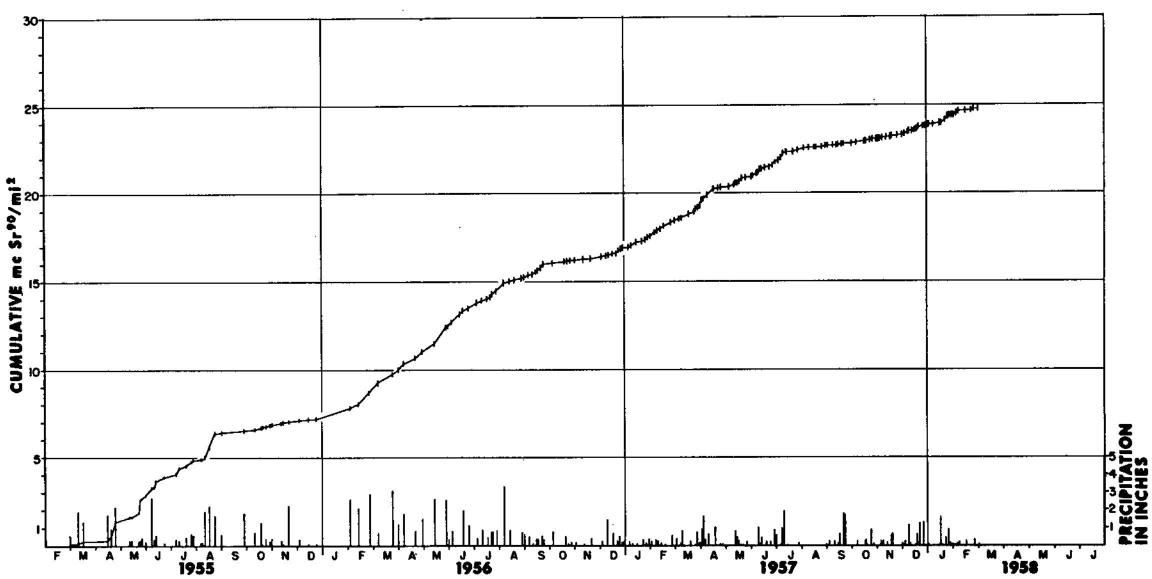

Fig. 2—Sr^{90} in Pittsburgh fallout. (Galvanized tub collections.)

ANNOTATED BIBLIOGRAPHY ON LONG-RANGE EFFECTS OF FALLOUT FROM NUCLEAR EXPLOSIONS*

(Papers published since the Congressional Hearings of 1957)

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1. Alba, A. Fernando, Beltran, Virgilio, Brody, T. A., Lezama, Hugh, Moreno, A., Tejera, M. A., and Vazquer, B. PRELIMINARY INFORMATION ON STUDIES OF RADIOACTIVE RAIN. *Revista mexicana de fisica* 5, 153-66 (1956).
   Data on radioactive rain, which were obtained by the gummed leaf method and by collection in a free surface of water are presented. The experimental methods are described. Some conclusions are obtained on the relative efficiency of the two methods and their relations to atmospheric precipitation.

2. Allen, J. S. A-BOMB FALLOUT IN NORTHERN WEST VIRGINIA. *West Virginia University Bulletin,* Series 56, 55-57 (1957).

3. Anderson, Ernest C., Schuch, Robert L., Fisher, William R., and Langham, W. RADIOACTIVITY OF PEOPLE AND FOODS. *Science* 125, 1273-78 (1957).
   Measurements of the Cs^{137} content of people and of foodstuffs indicate that this nuclide is unlikely to be a decisive factor in the long-term hazards from weapons testing and reactor waste disposal. The amount of Cs^{137} now present in the population of the United States averages 0.006 microcurie and shows no marked dependence on geographic location. The average radiation dose received from Cs^{137} is one-twentieth of that received from natural radiopotassium and 1 per cent of the average total dose from all natural sources. Because of the short biological half life of cesium of about 140 days, it does not accumulate in the body as does Sr^{90}. The study of the distribution of Cs^{137} is being continued to furnish information on the mechanisms of the fallout process and provide a measure of the rate of fallout and of stratospheric storage.

4. Armagnac, Alden P. WILL BOMB DUST ENDANGER YOUR HEALTH? *Popular Science* 170, 163-67, 256, 258, and 260 (1957).

5. ATOMIC ENERGY IN ITS REPERCUSSIONS ON LIFE AND HEALTH. Papers from a Scientific Conference held at the National Museum of Natural History, July 1-2, 1955. Paris, L'Expansion Editeur, 254 p. (1956) (in French).
   The papers given at the July 1955 conference in Paris on the dangers of atomic energy and radiation are presented. Topics discussed include the dangers inherent in atomic

*This report has also been issued as AEC report NYO-4753 (Supplement 2).

equipment; the radioactive effects of atomic explosions; a review of the analyses made in Japan of the radioactive ash from the March 1954 Bikini explosions; long distance propogation and characteristics of the radioactive particles emitted in atomic explosions; eventual influences of atomic explosions on evolution; radioactivity in air and rain; radioactive clouds; meteorological effects of atomic explosions; a general review of the biological effects of ionizing radiation; medical problems posed by the immediate effects of atomic explosions; cataracts received from explosions or research in atomic energy; atomic radiation and aquatic life; biological danger from powders emitting beta rays; effect of weak doses of radiation; ionizing radiation and the gases in atomic industry; and therapy for radiolesions.

6. Auerback, C. BIOLOGICAL HAZARDS OF NUCLEAR AND OTHER RADIATIONS. *Nature* 178, 453-54 (1956).

   A comparison of authoritative digests by Great Britain and the United States was discussed. Both reports show that the present dangers arise much more from excessive use of x-rays than from bomb fallout or from atomic energy establishments.

7. Blifford, I. H., Friedman, H., Lockhart, L. B., and Baus, R. A. GEOGRAPHICAL AND TIME DISTRIBUTION OF RADIOACTIVITY IN THE AIR. *Journal of Atmospheric and Terrestrial Physics* 9, 1-17 (1956).

   A report on the results of continuous measurements on both natural and fission product radioactivity of the air at ground level over a 5-year period beginning in 1950.

8. Blifford, I. H., Friedman, H., Lockhart, L. B., and Baus, R. A. RADIOACTIVITY OF THE AIR. Naval Research Laboratory Report No. 4760. Office of Technical Services, Washington 25, D. C. Report No. PB121222.

   Since 1949 the Naval Research Laboratory has operated stations for the detection and collection of atmospheric radioactivity. This report presents an analysis of some of the results obtained. The concentrations in curies/cc of fission products in the air at ground level from early 1951 through late 1954 is given in graphical form for a number of locations in various parts of the world. Maximum activities of the order of 10^{-16} curie/cc were recorded after atomic explosions. It is apparent that the distribution of activity throughout the earth's atmosphere is not uniform. Correlations which have been made with both low and high level wind trajectories, seem to show that the clouds of fission activity follow fairly restricted paths. In considering the distribution of fission products from atomic explosions, it will not be valid to assume a uniform distribution in the total atmosphere of even one hemisphere.

9. Blifford, I. H. and Lockhart, L. B. RADIOACTIVITY OF THE AIR AND FALLOUT SAMPLES COLLECTED AT SITES ON THE 80th MERIDIAN DURING OCTOBER 1956. Naval Research Laboratory Problem A02-13, Project No. NR 612 130. 3p. (1956).

10. Boroughs, H. METHOD OF PREDICTING AMOUNT OF STRONTIUM-89 IN MARINE FISHES BY EXTERNAL MONITORING. *Science* 124, 1027-28 (1956).

11. British Atomic Scientists Association. STRONTIUM HAZARDS. *The Lancet* 878-9 (April 27, 1957).

12. Campbell, Charles I. RADIOSTRONTIUM FALLOUT FROM CONTINUING NUCLEAR TESTS. *Science* 124, 894 (1956).

    Published data on the fallout of radiostrontium from nuclear tests are reviewed. Assuming a 10-year storage time and continuing test rate about twice that previously estimated, it is calculated that the Sr^{90} accumulated on the ground after about 35 years would be 80 cm/mi^2. This would correspond to about 0.14 MPC units in the soil.

13. Caster, W. O. STRONTIUM-90 HAZARDS. *Science* 125, 1291-92 (1957).

14. Chapman, N. G. and Humphrey, R. W. AN INVESTIGATION OF THE VARIATION OF THE ATMOSPHERIC RADIOACTIVITY AT WELLINGTON FROM 5 MAY TO 18 JULY 1955. *New Zealand Journal of Science and Technology*, Section B 37, No. 3, 396-406 (1955).

    The collection apparatus was situated 9 m above the local ground level and 130 m above sea level. The filter paper collection method was used, a description of the apparatus used and a discussion of the efficiency of this method being included. In this discussion a lower limit for the average value of the radon content in the period of 37×10^{-18} curie/cm^3 is obtained. A diurnal variation in the radon content was found which showed principal and secondary minima, the principal at about 12 to 14 hr N.Z.M.T. and the secondary at 20 to 21 hr N.Z.M.T. The effect of wind speed on the radioactive content is shown and some indications obtained regarding the influences of wind direction, barometric pressure, and rainfall. From the results, approximate upper limits for the amount of fission product activity present in relation to the amount of natural radioactivity in the atmosphere at this locality have been obtained.

15. Clayton, C. G. RADIOACTIVE CONTAMINATION OF FOODS FROM FALLOUT AS A SOURCE OF ERROR IN SOME ANIMAL EXPERIMENTS. *Nature* 179, 829-30 (1957).

Radioactivity in control animals since 1956 has increased so as to vitiate experiments. The activity of foods used was measured. The counts are given for rat cubes, milk, peas, sugar, flour, cabbage, carrot, cauliflower, salt, semolina, and water. The high count of the cabbage is probably from Cs^{137} present at 4 micromicrocuries per gram.

16. Cockcroft, John. RADIOACTIVE POLLUTION FROM NUCLEAR EXPLOSIONS. *Smokeless Air* 25, 192-96 (Summer 1955).

Because it produces 100 to 1000 times more radioactive material than an atomic bomb, the hydrogen bomb is the most important source of radioactive material. If a hydrogen bomb is exploded on the ground millions of tons of soil, ranging in size from 0.02 in diameter down to 0.001 inches, will be mixed with the radioactive products, the larger particles settling near the scene of the blast, and the remainder dispersing in the stratosphere—above 50,000 feet. In the case of an air burst practically all of the radioactivity will go into the stratosphere and from there be deposited uniformly. The author calculates that the contribution of radioactivity from weapons tests is small, considerably less than the radiation exposure received from natural sources of radioactivity, if the tests continue at the present level. However, in the case of a full-scale hydrogen bomb war, the hemisphere contamination would correspond to a dose of about 25 r which could be damaging to future generations. Operation of nuclear plants for power, although sources of large amounts of radiation, can be controlled to minimize the radiation levels to the population. The major source of such contamination, radioactive wastes, can be handled through separation of the more hazardous strontium and cesium from the bulk of the wastes, storage of the residue for about 10 years followed by controlled release, and utilization of the separated cesium and strontium as by-product materials pending development of more satisfactory methods of handling and disposal.

17. Comar, C. L., Trum, Bernard F., Kuhn, U. S. G., Wasserman, R. H., Nold, M. M., and Schooley, J. C. THYROID RADIOACTIVITY AFTER NUCLEAR WEAPONS TESTS. *Science* 126, 16-19 (1957).

18. Cronkite, E. P., Bond, V. P., and Dunham, C. L. SOME EFFECTS OF IONIZING RADIATION ON HUMAN BEINGS. STUDY OF ACCIDENTAL DEPOSIT OF RADIOACTIVE MATERIAL ON INHABITED PACIFIC ISLANDS FOLLOWING DETONATION OF THERMONUCLEAR DEVICE. Washington, U. S. Government Printing Office. Catalogue No. Y3.At 7:22/TID-5338. 106p. $1.25.

This report concerns the Marshallese and Americans accidentally exposed to radiation from fallout following the explosion of March 1, 1954, and includes a discussion of radiation injury in the human being. Radiation surveys of the areas revealed injurious radiation levels on inhabited atolls and evacuation was ordered immediately. The degree of radiation injury was assessed as quickly as possible, and appropriate care and study of the injured was instituted without delay. The initial data have been supplemented by field surveys 6 and 24 months after the original investigation. The results of this work are summarized.

19. Crosthwait, L. B. MEASUREMENT OF ATMOSPHERIC AND RADIOACTIVITY AT WELLINGTON. *New Zealand Journal of Science and Technology*, Section B 37, No. 3, 382-4 (1955).

A filter paper method of collecting atmospheric radioactivity is described. The mean radon concentration found by this method was 34×10^{-18} curie/cm^3.

20. "DIRT" FROM "CLEAN" BOMBS. *Science News Letter* 72, 3 (1957).

21. Dubinin, N. P. PROBLEMS OF RADIATION GENETICS. *Vestnik Akademii Nauk S.S.S.R.* 26, No. 8, 22-3 (1956) (in Russian).
A general review is presented of recent experiments in genetics. Mutant and hereditary effects of the increase in natural radiation and that released by atomic and hydrogen tests were analyzed. Achievements and the possibilities of applying radiation in the induction of selective plant mutations are discussed.

22. THE EFFECTS OF NUCLEAR WEAPONS. Samuel Glasstone, ed. Washington, U.S. Government Printing Office, (1957), 587p. $2.00.
The most recent data concerning the effects associated with explosions of nuclear weapons are presented. The data have been obtained from observations made of effects of nuclear bombing in Japan and tests carried out at the Eniwetok Proving Grounds and Nevada Test Site, as well as from experiments with conventional explosives, and mathematical calculations. The volume is intended for use in planning against possible nuclear attack.

23. Eisenbud, Merril. GLOBAL DISTRIBUTION OF STRONTIUM-90 FROM NUCLEAR DETONATIONS. *Scientific Monthly* 84, No. 5, 237-44 (1957).
Presented at the Washington Academy of Sciences Fall Symposium, Washington, D.C., on November 15, 1956.

24. FALLOUT AND RADIATION HAZARDS EXPERTS DISAGREE. *Chemical and Engineering News* 35, 16-19 (June 24, 1957).
Over 30 experts in the fields of physics, biology, and genetics outlined what is known about radiation and its hazards and especially on the fallout problem before a special Subcommittee on Radiation of the Joint Committee on Atomic Energy. Expert opinion on the fallout problem is far from unified, but there seems to be accord on these points: (1) To date, accumulation of radioactivity from fallout has not been large; (2) A completely "clean" bomb causing no fallout, is apparently impossible; (3) Of the many radioactive materials released by nuclear explosions, strontium-90 is easily the most important; (4) Fallout is hazardous, to a degree, and some limitation on the injection of fission products into the atmosphere is desirable; and (5) It is not yet known how little radiation causes damages to man. Two points on which there is widest disagreement are uniformity of fallout throughout the world, and the biological effects of low level radiation to man. Various views on these points were presented. It is generally agreed that more research is needed on all these points.

25. FEWER TORNADOES IN AREAS OF THE ATOMIC CLOUDS. *U. S. News and World Report* 106 and 108 (April 29, 1955).

26. Garrigue, Hubert. RADIOACTIVITY OF AIR AND PRECIPITATIONS. *Comptes Rendus* 243, 584-85 (1956) (in French).
Since May 31, 1956, all the precipitations at the summit of the Puy-de-Dome, have been contaminated with artificial radioactive products. The flight survey of June 15 confirms these results.

27. Honda, M. A PROPOSED METHOD OF ANALYSIS OF RADIOACTIVE SUBSTANCES IN RAIN WATER. *Japan Analyst* 3, 368 (1954).
Ion exchange, using Amberlite IR-120 and Dowex 50 cation exchange resins, is proposed as a method of analysis of radioactive substances in rain water.

28. Hunter, C. G. RADIATION INJURIES IN ATOMIC WARFARE WITH STRESS ON FALLOUT. *Canadian Medical Association Journal* 76, 394-401 (1957).

29. Jacobs, Paul. CLOUDS FROM NEVADA; A SPECIAL REPORT ON THE AEC'S WEAPONS-TESTING PROGRAM. *The Reporter* 16, 10-29 (1957).

30. Kellogg, W. W., Rapp, R. R., and Greenfield, S. M. CLOSE-IN FALLOUT. *Journal of Meteorology* 14, 1-8 (1957).

The phenomenon of radioactive fallout from an atomic explosion is described, and a quantitative technique for determining the distribution of radioactive material on the ground is developed. The primary factors which must be considered are wind field, yield and height of burst, and particle-size distribution. Certain parameters which enter directly into a fallout determination are given quantitatively, such as the altitude and size of the atomic cloud (as a function of explosion yield and atmospheric stability) and particle fall-rates (as a function of altitude and particle size). Two hypothetical fallout patterns for a one-megation explosion, computed on a high-speed digital computer are presented, showing the large effect which the wind has in determining the character of the fallout. The meteorological problems associated with a fallout prediction are discussed.

31. Kimura, Kenjiro. ANALYSIS OF RADIOACTIVE FALLOUT OF THE ATOMIC BOMB EXPLOSION ON BIKINI. *Radioisotopes (Japan)* 3, 1-4 (1954).

The radioactive fallout was found to contain 55.2, 7.0, 11.8, and 26.0% of CaO, MgO, CO_2, and H_2O, respectively, the chief constituent being $Ca(OH)_2$. The electric-spark method of analysis showed the presence of Al, Fe, and Si in addition to Ca and Mg. Its decay curve followed $I = ct^{-1.37}$, where I represents radioactivity, t, time since the explosion took place, March 1, 1954, and c, const. Its specific activity measured on April 23, 1954, was 0.37 mc/g. Radioactive nuclei identified by March 26 were Sr^{89}, Sr^{90}, Y^{91}, Sr^{95}, Nb^{95m}, Nb^{95}, Ru^{103}, Rh^{106}, Te^{129m}, Te^{129}, Te^{132}, I^{131}, I^{132}, Ba^{140}, Ce^{141}, Ce^{144}, Pr^{143}, Pr^{144}, Nd^{147}, Pm^{147}, S^{35}, Ca^{45}, U^{237}, and Pu^{239}.

32. Kimura, Kenjiro. INTRODUCTION TO SPECIAL COLLECTION OF PAPERS. ANALYSIS OF THE BIKINI ASH. *Japan Analyst* 3, 333-34 (1955).

The incident of the Bikini ashes and the fishing boat is reported. Experiences on the boat are recorded, and fallout analyses are compared with those of Nagasaki and Hiroshima.

33. Kimura, Kenjiro, Ikeda, Nagao, Kimura, Kan, Kawanishi, H., and Kimura, M. RADIOCHEMICAL ANALYSIS OF THE BODY OF THE LATE MR. KUBOYAMA. *Radioisotopes (Japan)* 4, 22-7 (1956).

Analyses were carried out of various organs of Mr. Kuboyama 200 days after he had exposed himself to radiation of the atomic bomb explosion on Bikini Atoll, March 1954. By ion-exchange chromatography, the presence of the following nuclides was indicated: Ce^{144} and Pr^{144} in the bone (I) (20×10^{-12} counts/g. fresh wt.). Liver (II), and Kidneys (III); Zr^{95} and Nb^{95} in II and III; Ru^{106}, Rh^{106}, Te^{129m}, and Te^{129} in I, III, and muscles; and Sr^{89}, Sr^{90}, and Y^{90} in I, II, and III. Activities found in these organs were decidedly higher than those found in the control samples obtained from individuals who died of other than the so-called radiation sickness. Radiation dose received by the bones of Mr. Kuboyama was calculated to be approximately 8 rep.

34. Kulp, J. Laurence, Eckelmann, Walter R., and Schulert, Arthur R. STRONTIUM-90 IN MAN. *Science* 125, 219-225 (February 8, 1957).

The world-wide average strontium-90 content of man was about 0.12 micromicrocurie per gram of calcium (/10,000 of the maximum permissible concentration) in the fall of 1955. A few values as high as 10 times the average have been obtained. This value is in accord with the predicted value based on fallout measurements and fractionation through the soil-plant-milk-human chain. With the present burden of strontium-90, this average level should rise to 1 or 2 micromicrocuries of strontium-90 per gram of calcium.

35. Langham, Wright H., and Anderson, Ernest C. STRONTIUM-90 AND SKELETAL FORMATION. *Science* 126, 205-06 (1957).

36. Lapp, Ralph. INTERVIEW BY MIKE WALLACE. ABC Television Network, Sunday, June 9, 1957. 15p.

37. Lapp, Ralph. STRONTIUM LIMITS IN PEACE AND WAR. *Bulletin of the Atomic Scientists* 12, No. 8, 287-9 and 320 (1956).

38. Lapp, Ralph, Kulp, J. L., Eckelmann, W. R., and Schulert, A. R. STRONTIUM-90 IN MAN. *Science* 125, 993-34 (1957).

Biological hazards from fallout Sr^{90} following nuclear explosions are discussed.

39. Lewis, E. B. LEUKEMIA AND IONIZING RADIATION. *Science* 125, 965-972 (1957).

40. Libby, Willard F. DEGREE OF HAZARD TO HUMANITY FROM RADIOACTIVE FALLOUT FROM NUCLEAR WEAPONS TESTS. (A letter from Dr. Libby to Dr. Schweitzer). *Bulletin of the Atomic Scientists* 12, 206-7 (1957).

41. Libby, Willard F. RADIOACTIVE FALLOUT.
Remarks prepared by Dr. Willard F. Libby, Commissioner, U. S. Atomic Energy Commission for delivery before the spring meeting of the American Physical Society, Washington, D. C., April 26, 1957.

42. Libby, Willard F. WHAT THE ATOM CAN DO TO YOU AND FOR YOU. *U. S. News and World Report* 64-70 and 73-77 (May 17, 1957).

43. Machta, L. and List, R. J. STRONTIUM-90 MAIN HAZARD. *Science News Letter* 71, 214 (1957).

44. Machta, L. and List, R. J. WORLD-WIDE TRAVEL OF ATOMIC DEBRIS. *Science* 124, 474-77 (1956).
The dispersal of radioactive airborne particles from two nuclear tests in the Pacific Proving Grounds of the AEC was traced by counting the activity on sheets of gummed film exposed at stations located throughout the world. A series of maps illustrate the fallout dispersal pattern at various times following the test shots. The effects of prevailing meteorological conditions on fallout dispersal and deposition are discussed.

45. METEOROLOGICAL ASPECTS OF ATOMIC RADIATION. *Science* 124, 105-12 (1956).
Bomb energy, detonation altitude, and atmospheric conditions have significant influences on the mechanism, rate, and pattern of fallout. These variables are discussed. Also considered is the possibility of an intolerable Kr^{85} concentration in the atmosphere from nuclear power plants.

46. Moloney, William C. LEUKEMIA IN SURVIVORS OF ATOMIC BOMBING. *New England Journal of Medicine* 253, 88-90 (1955).

47. Muller, Hermann J. AFTER EFFECTS OF NUCLEAR RADIATION. *National Safety News, American Society of Safety Engineers* 74, 42-8 (1956).

48. Nagasawa, Kakuma, Kawashiro, Iwao, Kawamura, Shoichi, Takenaka, Yusuki, and Nishizaki, Sasao. RADIOCHEMICAL STUDIES ON RADIOCONTAMINATED RICE CROPPED IN NIIGATA PREFECTURE IN 1954. *Bulletin of the National Hygienic Laboratory, Tokyo* No. 73, 187-90 (1955).
Radioactivity of various parts of rice seeds cropped in 1954 was determined and compared with that of 1953. Radioactivity due to K^{40} was established as total count of the ash and was subtracted for correction. None of the rice seeds in 1953 showed excess radioactivity. With the seeds in 1954 the following results were obtained: unhulled rice 3-6 cpm/g; chaff 3-6 cpm/2 g; unpolished rice 0-0.3 cpm/8 g; polished rice 0; rice bran 0. This radioactivity is thought to come from the rain, adherent to the chaff, but not from soil contamination.

49. Nagasawa, Kakuma, Kawashiro, Iwao, Kashima, Tetsu, Kawamura, Shiochi, Nishizaki, Sasao, and Matsushima, Takashi. STUDIES ON RADIOCONTAMINATION OF FOODSTUFFS EFFECTED BY A- OR H-BOMB EXPLOSION II. RADIOCONTAMINATION ON GREEN TEA. *Bulletin of the National Hygienic Laboratory, Tokyo* 31, No. 6, 201-3 (1956).
More radiation than those for natural K^{40} was found in 4 of 16 samples of green tea and another 3 samples sent from Professor Shiokawa who had found artificial radiation in them. The authors suggested the contamination of these samples was limited only to the surface, on which the radiocontaminated rain had dried up and not to the absorption of tea plants.

50. Nagasawa, Kakuma, Kawashiro, Iwao, Enomoto, Masayoshi, Matsushima, Takashi, and Kawamura, Shoichi. STUDIES OF RADIOCONTAMINATION OF FOODSTUFFS EFFECTED BY A- OR H-BOMB EXPLOSION. III. RADIATION OF MILK AND ITS PREPARATIONS.

Bulletin of the National Hygienic Laboratory, Tokyo, 31, 205-7 (1956).

No artificial radiation was found in any of 32 samples of milk of cows fed on the weeds which were supposed to have been contaminated with fission products in the rain. The researchers who reported finding artificial radiation in the milk in Japan appear to have mistaken natural K^{40} radiation for artificial radiation.

51. Nagasawa, Kakuma, Kawashiro, Iwao, Enomoto, Masayoshi, Kashima, Tetsu, and Matsushima, Takashi. STUDIES ON RADIOCONTAMINATION OF FOODSTUFFS EFFECTED BY A- OR H-BOMB EXPLOSION. IV. RADIOCONTAMINATION OF DRINKING WATER, VEGETABLES AND FRUITS IN JAPAN CAUSED BY H-BOMB EXPLOSIONS AT BIKINI ATOLL, 1954. *Bulletin of the National Hygienic Laboratory, Tokyo,*31, No. 6, 209-12 (1956).

The vegetables collected from various parts of Japan from May 19th to 30th, 1954 were considerably contaminated with radioactivity, though they were almost free from radiation after being washed. The dried and ash samples of some vegetables collected from August 30 to September 7, 1954 showed almost no artificial radiation. The radiation in rain water, tank water and well water collected from various parts of Japan from May to August 1954 were examined.

52. Nagasawa, Kakuma. STUDIES OF RADIOCONTAMINATION OF FOODSTUFFS AFFECTED BY A- OR H-BOMB EXPLOSIONS. V. RADIOCONTAMINATION OF SEA FISH AND ITS RADIOCHEMICAL ANALYSIS. *Bulletin of the National Hygienic Laboratory, Tokyo* 31, No. 6, 213-229 (1956).

53. Nagasawa, Kakuma, Nakayama, Goichi, Serizawa, Jun, and Nishizaki, Sasao. STUDIES ON RADIOCONTAMINATION OF FOODSTUFFS AFFECTED BY A- OR H-BOMB EXPLOSION. VI. ON THE EFFECT UPON LIVER OIL PRODUCTION BY THE USE OF RADIOCONTAMINATED FISH LIVERS AS A STARTING MATERIAL. *Bulletin of the National Hygienic Laboratory, Tokyo* 31, No. 6, 209-12 (1956).

The authors measured the radiation in each fraction in the process of liver oil production by the use of radiocontaminated liver as a starting material. In the result, almost no radioactivity was found in the liver oil; most of it was found in the residue and the waste. Therefore, it was easy to prepare liver oil from the liver with radiocontamination from A- or H-Bomb explosion experiments, 1954.

54. Nakano, Shoichi. STUDIES OF THE ANALYTICAL CHEMISTRY ON FILTER PAPER. XVI. PAPER CHROMATOGRAPHY OF RADIOACTIVE SUBSTANCE. RADIOCHEMICAL STUDIES ON "BIKINI ASHES." *Bulletin of the Chemical Society of Japan* 29, 219-24 (1956).

Radioactivity from "Bikini ashes" and U^{235} fission is divided into 3 major groups by ion-exchange methods and then subdivided by paper chromatography. In the first group, TeO_4^{-2}, SO_4^{-2}, PO_4^{-3}, and I^-, as well as two Ru^{106} spots are resolved in filter paper by iso-AmOH, Cs^{137} and Ce^{144} from the second and Y^{90} and Sr^{90} from the third group are separated also. It is shown that the presence of carrier or foreign elements alters the chromatographic behavior of the tracers.

55. Natanson, G. L. RADIOACTIVE AEROSOLS. *Uspekhi Khimii* 25, 1429-45 (1956) (in Russian).

Tabulations are given presenting various published data on safe atmospheric concentrations of various radioactive and nonradioactive aerosols. Methods of determination of active aerosol concentrations and dispersion as well as the technical applications of "labeled" aerosols are discussed. The effect of atomic explosions are analyzed considering the "nominal" atomic bomb based on U^{235} and Pu^{232} equivalent to 20,000 tons of TNT.

56. Pace, F. C. EFFECTS OF ATOMIC BOMB RADIATIONS ON HUMAN FOOD. *Canadian Journal of Public Health* 47, 113-141 (1956).

The increase in energy release of atomic weapons has increased the hazard of atomic radiation to food. Products of atomic explosions are probably similar regardless of size. Of the energy released, blast energy accounts for one-half, heat flash for one-third, initial nuclear radiation for one-twentieth, and residual radiation (potential fallout) about one-tenth. Radioactive elements may enter man by inhalation, by open wounds, or by ingestion of contaminated food. Food can become contaminated by direct fallout on unprotected food or through metabolic assimilation by plants or animals. Dust-proof containers and undamaged cans provide protection from the first hazard. Cans, etc., should be washed before opening. Other food could be cleaned and used if subsequent monitoring indicated that the fallout material had been removed.

57. Patterson, R. L. and Blifford, I. H. ATMOSPHERIC CARBON-14. *Science* 126, 26-28 (1957).

58. Pinke, A. S. LIMITATION OF FISSIONABLE MATERIAL IN WEAPONS. *Bulletin of the Atomic Scientists* 13, 177-8 (1957).

59. Poling, James. BOMB-DUST RADIATION. *Better Homes and Gardens* 35, No. 5, 71, 172, 174, 179, and 182-3 (1957).

60. Russell, W. L. SHORTENING OF LIFE IN THE OFFSPRING OF MALE MICE EXPOSED TO NEUTRON RADIATION FROM AN ATOMIC BOMB. *National Academy of Sciences* 43, 324-329 (1957).

61. Romney, E. M., Neel, J. W., Nishita, H., Olafson, J. H., and Larson, K. H. PLANT UPTAKE OF Sr^{90}, Y^{91}, Ru^{106}, Cs^{137}, and Ce^{144} FROM SOILS. *Soil Science* 83, 369-376 (1957).

62. Saal, Herbert. WHAT IS THIS STRONTIUM 90 BUSINESS? *American Milk Review* 18, 30, 32, and 34 (1956).

63. Saiki, Masamichi. ON THE RADIOELEMENTS OF FISHES CONTAMINATED BY THE NUCLEAR BOMB TEST. *Japan Analyst* 7, No. 7, 443-9 (1957).

64. Sandor, Szalay and Denes, Berenyi. OBSERVATIONS OF UNUSUAL RADIOACTIVITY IN PRECIPITATIONS WHICH FELL IN BEBRECEN BETWEEN APRIL 22 – DECEMBER 31, 1952. *Magyar Tudomanyos Akademia, Budapest,* 13p. (1955) (in Hungarian).

It is suggested that radioactive fallout may be useful for the meteorological study of the movement of air masses, if an international organization records fission fragment concentration after atomic test explosions.

65. Schumann, G. ARTIFICIALLY RADIOACTIVE PRODUCTS IN THE ATMOSPHERE. *Zeitschrift für angewandte Physik* 8, 361-4 (1956).

The by-product activity arising from atom bomb test was investigated in Heidelberg by a filtration method during March 1953. The measurement of the activity on the filter was accomplished by a cylindrical beta-counter. The decay was proportional to $t^{-}(1 + x)$, where x is of the order of magnitude of 0.1, and thus approaches t^{-1}. The time of explosion can be determined by extrapolation of the reciprocal activity as a function of time.

66. Setter, L. R., Hagee, G. R., and Straub, C. P. ANALYSIS OF RADIOACTIVITY IN SURFACE WATERS. PRACTICAL LABORATORY METHODS. *American Society for Testing Materials Bulletin,* No. 227, 35-40 (1958).

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tration with selective elution of Y^{90} is described. Low-level techniques are employed to count the Y^{90} which reflects the concentration of Sr^{90}. Twenty-six liters of city tap water were concentrated and found to contain $3.10 + 0.21 \times 10^{-4}$ dpm/ml of Sr^{90}. If interferring activities are present, the Sr^{90} can be eluted and radiochemical separation performed.

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A review of radioactive dust.

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Ashes obtained from contaminated trifolium repens, astragalus sinicus, and rumex japonicus were studied. The precipitate obtained by treating the acidic solution of the ash with H_2S followed by Fe^{+2} in the presence of NH_3 and NH_4Cl contained Y, Sr, and the rare earth elements.

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Marked regional differences in the Sr content of human bones were observed as a result of the analyses of 277 human bones from a world-wide sampling. The % Sr/% Ca $\times 10^3$ ratio was determined on bones ashed at 800° for 12-24 hours. This ratio was not affected by bone type, age, or sex. Bones from Brazil and Liberia had high average ratios, Denmark, Italy, and Japan, intermediate average ratios, and Cologne, Switzerland, and Bonn low average ratios (1.33, 1.25, 0.89, 0.71, 0.70, 0.36, 0.35, and 0.35, respectively). Analyses of bones of 9 other regions were also reported.

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In 2 specimens of Tridacna Gigas recovered from the shores of Rongelap Island 2 years after the March 1954 nuclear detonation, readily detectable amounts of both beta- and gamma-radiation were present. The activity was attributable to Co^{60} (I) to the extent of 63 and 85% of the gross gamma-activity. As it is not a component of fission products, it is assumed that it was induced from an environmental precursor possibly Co^{59}, by the

neutron flux accompanying the detonation. It was not detected in samples collected one year after the detonation; this points to an enormous concentrating capacity of Tridacna Gigas.

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Ashed sample of the muscle tissue of shipjack, which were caught by "Shunkotsu-Maru" on June 19th near Bikini Atoll was used for the present study. Ion-exchanger method, using Dowex 50, was applied to separate radioactive elements with 0.2 N HCl, 0.5% oxalic acid and 5% ammonium citrate (pH 3.53, 4.18, 4.60, 5.02, 5.63, and 6.42) as the eluents. Elution curve of the ashed muscle is shown in Figure 1. Appreciable amounts of cathionic radioactive elements were separated by 0.5% oxalic and by 5% ammonium citrate at the pH of 4.18 and also anionic radioactive elements were obtained by 0.2 N HCl. As the fraction, which can be withdrawn by ammonium citrate as pH 4.18, was proved the most active; further analysis was undertaken according to the scheme cited in Figures 2 and 5. In addition to this chemical separation, absorption curve of this specimen with tin foil was examined simultaneously (Figure 3) and thus the radioactive Zn^{65} was confirmed to be present in the fish muscle. Although it was difficult to detect radioactivity in rare-earth and alkaline-earth groups in the muscle tissue, attempts are being made for more precise examination.

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A dose was estimated to be 120 r in 24 hours or 270 r in 13 days when calculated according to $t^{-1.2}$; pr 240 r in 24 hours or 440 r in 13 days when calculated according to $t^{-1.4}$, observed value of decay, and supposing exposure to the radiation began 6 hours after the explosion had occurred on Bikini.

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An electric precipitator is used to collect dust in the air because its collection efficiency for radioactive substances is up to 10 times that of the impactor of filter paper types. About 10 m^3 of air is filtered during 5 hours, and the trapped dust is measured more than 24 hours after collection to avoid the influences of naturally active substances. The average radioactivity of the air is approximately 10^{-16} curie/cc. During the period of observation 4 peaks occurred. The dates and maximum levels of artificial activity, respectively, are November 4-10, 1954, 1.2×10^{-7} μc/liter; April 11-13, 1955, 4.3×10^{-8} μc/liter; November 25-8, 1955, maximum unknown; and March 22-5, 1956, 1.0×10^{-7} μc/liter. The presumed dates and places of detonation corresponding to the peaks are October 31, 1954 northwest of Japan; March 29, 1955, Nevada, U.S.A.; November 22, 1955, near L. Baikal, U.S.S.R.; and March 13-15, 1956 unknown.

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Following a fallout estimated at 0.2 micromicro/liter Trifolium repens, Astragalus sinicus, and Rumex japonicus were harvested and analyzed for radioactivity. Most of the

radioactivity (2300 – 4700 counts/min/50 g plant ash) was associated with oxalate precipitate. A small amount of activity in the Zn group is attributed to Zn^{65} produced by reaction Zn^{64} (n,γ) from Zn employed in the mechanical parts of the bomb. Sr-Ba radioactivity was 0.1 that of the rare earth group. Distribution of the radioactive elements was nearly the same as that found on the No. 5 Fukuryu-Maru.

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BIBLIOGRAPHY OF DOCUMENTS SUBMITTED TO THE UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION*

(Report A/AC.82/G/R.)

Argentina

G/R.23 PRELIMINARY REPORT ON POSSIBLE METHODS OF ESTIMATING THE BIOLOGICAL EFFECTS OF SMALL DOSES OF RADIATION

Among biological effects of small doses of radiation, emphasizes especially: measurement of DNA synthesis using P^{32}, C^{14}, and P^{35} radio-autography histochemical and electron microscopic examination of changes in lymphocytes and other components of peripheral blood.

G/R.28 INFORMATION SUMMARY ON THE PRELIMINARY WORK CARRIED OUT IN ARGENTINA FOR THE MEASUREMENT AND STUDY OF RADIOACTIVE FALL-OUT

Gives summary description of methods tried in Argentina for total fallout radioactivity.

G/R.80 A GEOLOGICAL, RADIO-METRIC AND BOTANIC SURVEY OF THE REGION "LOS CHAÑORES" IN THE PROVINCE OF MENDOZA OF THE ARGENTINE REPUBLIC

Radiometric data on the above-mentioned region are shown on the attachment to the document.

G/R.81 MEASUREMENTS OF THE COSMIC RAY EXTENSITY IN THREE LATITUDES OF THE ARGENTINE REPUBLIC

Data on the intensity of the Cosmic rays in 3 points of observation at different latitudes in Argentina.

G/R.81 (Corr. 1) Correction to above report.

G/R.82 ON THE ABSORPTION OF THE NUCLEONIC COMPONENT OF THE COSMIC RADIATION AT $-15°$ GEOMAGNETIC LATITUDE

G/R.83 MUTATIONS IN BARLEY SEEDS INDUCED BY ACUTE TREATMENTS BY GAMMA RAYS OF COBALT-60

A report of experiments on the induction of mutations at a number of loci in barley by irradiation of seeds with gamma rays of Co^{60} at 10 r/min.

G/R.83 (Add.1) Addendum to above report.

*A numerical cross reference of report numbers to countries is presented at the end of this Bibliography.

Argentina (Continued)

G/R.84 MUTATIONS IN BARLEY INDUCED BY FORMALDEHYDE
A report of experiments on the induction of mutations at a number of loci in barley by formaldehyde.

G/R.85 SPONTANEOUS MUTATIONS IN BARLEY
A report of experiments on spontaneous mutations at a number of loci in barley.

G/R.86 A STUDY OF RADIOACTIVE FALLOUT IN THE ARGENTINE REPUBLIC
Describes the methods used in the Argentine Republic for fallout collection and measurement. Value for Sr^{90} and total beta activity are given for the first two months of 1957.

G/R.87 A RESEARCH PROGRAMME IN THE ARGENTINE ON THE GENETIC INFLUENCE IN THE PLANTS OF THE IONIZING AND ULTRA-VIOLET RADIATION
A brief summary of projected research in Argentina on the genetic effects of ionizing and ultra-violet irradiations of plants, comprising both surveys of areas of high natural background and a broad range of laboratory experiments.

G/R.88 PROGRAMME OF PHYSICAL OCEANOGRAPHY FOR THE INTERNATIONAL GEOPHYSICAL YEAR

G/R.89 INFORMATION ON THE GENERAL PROGRAMME TO BE DEVELOPED IN THE ARGENTINE ON ITEMS OF INTEREST TO THE SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION
A brief general survey of Argentina research activities related to the effects and levels of ionizing radiations.

G/R.127 CALCIUM AND POTASSIUM CONTENT OF FOODSTUFFS IN THE ARGENTINE REPUBLIC

G/R.154 NORMAL CALCIUM CONTENT OF SAN JUAN WINES

G/R.157 RADIOACTIVE FALLOUT FROM THE ATMOSPHERE IN THE ARGENTINE REPUBLIC DURING 1957
Includes tables of results for first three-quarters of 1957. Total activity and Sr^{90} content is measured.

Australia

G/R.29 Report consisting of 6 parts, as follows:

(PART I) HUMAN GENETICS
Report gives recommendation as to the kind of human mutations which could be scored: several dominant autosomal genes should be investigated (gives list of such genetical abnormalities).

PART (II) PLANT GENETICS
Gives plan of research to be organized.

(PART III) RADIOBIOLOGICAL UNIT IN THE UNIVERSITY OF ADELAIDE
To be established.

(PART IV) NATURAL RADIATION BACKGROUND AND ENVIRONMENTAL CONTAMINATION
Describes future organization of investigations on natural radiation background and contamination; radioactivity of food will be determined.

(PART V) OCCUPATIONAL EXPOSURE IN AUSTRALIA
Describes monitoring system in application since 1940 and summarizes observations done by the use of film badges (gives statement of per cent of personnel having received a specified per cent of the permissible dosage).

Australia (Continued)

(PART VI) HEALTH AND SAFETY PRECAUTIONS IN URANIUM MINING AND MILLING IN AUSTRALIA
Describes health and safety precautions in uranium mining and milling.

Austria

G/R.19 INFORMATION PREPARED BY THE AUSTRIAN GOVERNMENT RELATING TO THE EFFECTS OF ATOMIC RADIATION
Describes radioactive warm springs at Bad Gastein, giving activity levels in water and air. Outlines wide scope of biological and instrumental research at Gastein Institute.

G/R.102 RADIOLOGICAL DATA. DEMOGRAPHIC DATA
Contains data on RBE dose rate in the gonad due to both natural and artificial sources. Demographic data of the whole population and of special groups are given.

Belgium

G/R.3 PRELIMINARY REPORT ON MODERN METHODS FOR THE EVALUATION OF THE BIOLOGICAL EFFECTS OF SMALL DOSES OF EXTERNAL RADIATION OR ABSORBED RADIOACTIVE MATERIALS
Concludes that the most hopeful measurements are those of: (1) DNases and cathepsins in plasma and urine; (2) DNA synthesis in vitro by bone marrow or biopsy specimens; (3) Platelet counts; (4) Antibody synthesis, and that the Committee should re-emphasize the need of appropriate fundamental research in radiobiology.

G/R.26 REPORT CONSISTING OF FIVE PARTS
1. Gives results of clinical observations of patients treated with X-rays, Ra or I^{131} and of persons occupationally exposed.
2. Gives results of studies relating to: the medical and physical control of persons occupationally exposed; the absorbing materials; and the radioactive contamination of the atmosphere.
3. Considers preventive or curative methods of syndromes of acute irradiation. States results of doses received by the occupationally exposed personnel of the *Institut du cancer* of Louvain, Belgium, and of hematological examinations of them.
4. Describes methods for measuring the radioactivity in rain and surface waters. Gives results of measures of radioactivity in rain waters.
5. Describes method for measuring the radioactivity of atmospheric dust by continuous filtering of air.

G/R.78 INFORMATION IN 8 PARTS ON HUMAN GENETICS SUBMITTED BY BELGIUM
Contains the Belgian memorandum on human genetics prepared for the Geneva meeting in April 1957 and a preliminary report on radioactive regions of Katanga (Belgian Congo). Besides this several reprints of Belgian contributions to radiobiology are presented. The topics included are: (1) Steroid metabolism in irradiated rat; (2) Endocrine response of irradiated animals studied by intraocular grafting; (3) Doses and hazards due to medical radiology; (4) Metabolism and toxicity of cystamine in the rat.
Part 1. Current uncertainties in the field of human genetics.
Part 2. A preliminary survey of vegetation and its radioactive content in the Katanga area.
Part 3. Influence of irradiation on the blood level of 17-hydroxycorticosteroids during the 24 hours following irradiation.

Part 4. Skin and depth doses during diagnostic X-ray procedures.

Part 5. General discussion of the need for methods of effective dose reduction in diagnostic X-ray procedures.

Parts 6 and 7. Chemical protection (a) metabolism of cystamine and (b) the effectiveness and toxicity of cystamine.

Part 8. Experiments on the ascorbic acid and cholesterol content of the suprarenals of the rat following irradiation of normal and hypophysectomised animals.

G/R.116 REPORT ON HEALTH PROTECTION IN URANIUM MINING OPERATIONS IN KATANGA

G/R.119 EFFECT OF A LETHAL DOSE OF RADIATION ON THE AMOUNT OF REDUCING STEROIDS IN THE BLOOD OF THE RAT

Indicates that lethal irradiation shows, in the blood, an increase of reducing steroids. This reaction presents a maximum which is not necessarily linked to the variations of the supra ascorbic acid and renal cholesterol.

G/R.120 ACTION OF HYDROGEN PEROXIDE ON THE GROWTH OF YOUNG BARLEY PLANTS

The growth of ocleoptiles of young barley plants treated with hydrogen peroxide is affected in the same way as when the plants are irradiated with X-rays.

G/R.121 ACTION OF CYSTAMINE AND GLUTATHIONE ON X-RAY IRRADIATED BARLEY SEED

The cystamine and glutathione diminish the effects of X-rays on barley grains; mitosis are still possible after doses which would inhibit them in the absence of these agents.

G/R.122 ACTION OF X-RAYS ON THE GROWTH OF INTERNODAL CELLS OF THE ALGA CHARA VULGARIS L.

Irradiation of internodal cells of *alga Chara Vulgaris L.* increases the elongation of these cells for doses up to 150 kr; above this dosage elongation is inhibited. c.f. G/R.156.

G/R.155 RECENT RESEARCH ON THE CHEMICAL PROTECTORS AND PARTICULARLY ON CYSTEAMINE-CYSTAMINE

Discusses the possible mechanisms of action of chemical radioprotectors particularly of those above-mentioned.

G/R.156 EFFECT OF X-RAYS ON THE GROWTH OF INTERNODAL CELLS OF THE ALGA CHARA VULGARIS L.

A complicated dose-effect relationship is shown when nondividing internodal cells are irradiated and their growth tested. c.f. G/R.122.

G/R.158 THE ACTION OF VARIOUS DRUGS ON THE SUPRARENAL RESPONSE OF THE RAT TO TOTAL BODY X-IRRADIATION

Describes strict difference in action of radioprotectors (cysteamine) or narcotic drugs (morphine and barbiturate) in preventing adrenal changes of irradiated animals.

G/R.159 NERVOUS CONTROL OF THE REACTION OF ANTERIOR HYPOPHYSIS TO X-IRRADIATION AS STUDIED IN GRAFTED AND NEWBORN RATS

Indicates that the changes of suprarenals after irradiation are consequence of a neuro-humoral chain reaction. The reaction of adrenals seems to have negligible importance in the pathogenesis of radiation disease.

G/R.209 RADIOACTIVE FALLOUT MEASURED AT THE CEN DURING 1955-56 AND 57

Describes methods and results of fallout measurements in the period 1955-57.

Belgium (Continued)

G/R.210 AVERAGE DOSES RECEIVED BY THE PERSONNEL OF CEN FROM 1954-1957
Summarizes the results of monitoring the professional exposure in nuclear energy education centre in Belgium. Film strips enables one to differentiate the exposure to beta, gamma, and neutron radiation. Only average doses of the personnel are given.

Brazil

G/R.34 and G/R.34 (Add.1) ON THE INTENSITY LEVELS OF NATURAL RADIOACTIVITY IN CERTAIN SELECTED AREAS OF BRAZIL
States that Brazil has areas of intensive natural background where thorium sands are present. Gives description of a survey on four sample areas which were selected with regard to: (1) the geological structure and genesis of their active deposits; (2) the extension, configuration and intensity of their radiometric levels; (3) the extent and variety of possible biological observations and experiments.

G/R.36 MEASUREMENTS OF LONG-RANGE FALLOUT IN RIO DE JANEIRO
Gives information on measurements of airborne activity in Rio de Janeiro, including tables showing decay curves of activity of samples and concentration of fission products in air during the period May–July 1956.

G/R.38 ABSORPTION CURVE OF FALLOUT PRODUCTS
Is connected with G/R.36; gives absorption curve for fission product of an airborne activity sample obtained by filtration.

G/R.169 ON THE NATURE OF LONG-RANGE FALLOUT
Describes one surprising high value of daily collected fallout activity due to a single big and highly active particle.

G/R.169 (Corr.1) Correction to above report.

G/R.188 SUMMARY–STRONTIUM-90 ANALYSIS IN DRY MILK AND HUMAN URINE

G/R.189 ON THE COMPOSITION OF LONG-RANGE FALLOUT PARTICLES
A single fallout particle of large dimensions and relatively high activity was found by daily monitoring of fallout. A detailed investigation of the nature and activity of this particle is presented.

G/R.190 ON THE UP-TAKE OF MsTh 1 IN NATURALLY CONTAMINATED AREAS
Gives preliminary results of an investigation on the uptake of natural radioisotopes by plants and animals in thorium-bearing area.

Canada

G/R.9 REPORT ON WASTE DISPOSAL SYSTEM AT THE CHALK RIVER PLANT OF ATOMIC ENERGY OF CANADA LIMITED
Describes procedures and results of ground dispersal of radioactive wastes from a natural U heavy water-moderated reactor.

G/R.10 THE CANADIAN PROGRAMME FOR THE INVESTIGATION OF THE GENETIC EFFECTS OF IONIZING RADIATION
Describes a proposal to modify the system of recording of the national vital statistics so as to render useful for genetic analysis the information contained in certificates of births, marriages, and deaths (see also WHO WP 1).

Canada (Continued)

G/R.12 LEVELS OF STRONTIUM-90 IN CANADA

Gives figures for Sr^{90} and Sr^{89} in milk powder at 7 stations, November 1955–May 1956. The Sr^{90} level averages 4.8 $\mu c/g$ Ca. Cumulative total beta activity and calculated Sr^{90} content of fallout analyzed by United States AEC from gummed papers, are summarized annually for 1953 to 1955. Independent Canadian measurements by methods which are not described differ from these by factors 2-5.

G/R.98 RADIOCHEMICAL PROCEDURES FOR STRONTIUM AND YTTRIUM

A detailed ion exchange procedure is given for the determination of radiostrontium in different samples. Methods are described for the treatment of various organic materials.

G/R.99 LEVELS OF STRONTIUM-90 IN CANADA UP TO DECEMBER 1956

Reports the results of radiochemical analysis for Sr^{90} activity in milk and milk products and human bone. Natural strontium content determination in milk and bone are also reported.

G/R.129 DOSE FROM UNSEALED RADIO-NUCLIDES

Calculations based upon information on shipments of radioisotopes show that the gonad dose to age 30 from unsealed radio-nuclides during 1956 in Canada is about 0.5% of the dose from the natural radiation sources. The main dose arises from I^{131}.

China

G/R.8 REPORTS BY THE ATOMIC ENERGY COUNCIL OF THE EXECUTIVE YUAN OF THE REPUBLIC OF CHINA

Briefly notes the radium content of certain Chinese and other waters and the occurrence of radioactive sailfish and dolphin in seas off Taiwan, June 1954.

Czechoslovak Republic

G/R.17 NATURAL RADIOACTIVITY OF WATER, AIR, AND SOIL IN THE CZECHOSLOVAK REPUBLIC

Briefly draws attention to deviations from reciprocity and to the partial reversibility of many radiation induced phenomena, to the possible use of organisms in a state of abiosis as integral dose-indicators, to certain specially radiosensitive organisms and responses, and to questions of threshold. An extensive survey reviews many studies of natural radioactivity.

Denmark

G/R.101 MEASUREMENT OF ACTIVITY OF AIRBORNE DUST. MEASUREMENTS OF FALLOUT DEPOSITED ON THE GROUND

Results of daily measured radioactivity in air (electrostatic filter method) and in precipitations (collection of rain water) in Copenhagen for the period 1956.

Egypt

G/R.46 PRELIMINARY REPORT ON ENVIRONMENTAL IODINE-131 MEASUREMENT IN SHEEP AND CATTLE THYROIDS IN CAIRO, EGYPT

Contains measurement of radioactivity of I^{131} deposited in thyroids of sheep and cattle which were brought from all over Egypt, Sudan, and north coast of Libya. Sampling was made during the period from May to October 1956.

Federal Republic of Germany

G/R.31 REPLIES TO THE QUESTIONS PUT BY THE UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION

1. Levels of natural radiation background.

2. Summarizes long-term research in biology and medicine under the direction of Langendorff (genetic effects); Rajewski (effects of natural radioactivity, accumulation of nuclides in tissues); Marquardt (research on natural mutation rates and their modification by irradiations); Other Institutes (pathological and physicochemical effect).

No details given – refers to scientific publications.

Food and Agricultural Organization of the United Nations

G/R.76 PRINCIPAL CALCIUM CONTRIBUTORS IN NATIONAL DIETS IN RELATION TO EFFECTS OF ATOMIC RADIATION FROM STRONTIUM 90

Gives a general idea of foods contributing to the calcium uptake of human beings in various parts of the world in relation to the different food habits of these people. Data still quite preliminary.

G/R.76 (Rev.1) PRINCIPAL CALCIUM CONTRIBUTORS IN NATIONAL DIETS IN RELATION TO EFFECTS OF ATOMIC RADIATION FROM STRONTIUM 90

G/R.165 GENERAL CONSIDERATION REGARDING CALCIUM AVAILABILITY IN THE BROAD SOIL GROUPS OF THE WORLD IN RELATION TO THE UPTAKE OF RADIOSTRONTIUM

Classified soil groups with low calcium level. Recommends the investigations of the factors influencing Sr^{90} uptake by plants growing on such soils.

France

G/R.16 REPORT OF 3 PARTS

The report includes three main parts:

1. Methods of measuring: the radioactivity produced by nuclear explosions and nuclear industry; natural or artificial radioactivity in living beings; the atmospheric radon.

2. Reports on measurements relative to: natural radioactivity of rocks; radioactivity of soil and water; natural and artificial radioactivity of air, water and soil, occupational radiation exposure.

3. Studies on genetic effects of radiations and on the descendants of patients treated with pelvic radiotherapy.

G/R.179 ATOMIC ENERGY COMMISSION. CENTRE OF NUCLEAR STUDIES AT SACLAY, GIF-SUR-YVETTE (SEINE ET OISE), FRANCE. TECHNIQUES AND RESULTS OF MEASUREMENTS OF RADIOACTIVITY IN THE ENVIRONMENT. MEASUREMENT OF ENVIRONMENTAL ACTIVITY: METHODS AND RESULTS

Gives results of measurements of both natural and artificial radioactivity in the environment.

G/R.179 (Corr.1) Correction to above report.

G/R.180 BIOLOGICAL METHODS AVAILABLE FOR USE IN THE QUANTITATIVE DETECTION OF IONIZING RADIATION

Surveys and evaluates the biological methods usable for the quantitative estimation of absorbed dose.

G/R.186 DOSES RECEIVED BY THE GENITAL ORGANS OF CHILDREN DURING X-RAY EXAMINATIONS

France (Continued)

Suggests the improvement of the radiological techniques and certain protective measures for decreasing of gonad dose from radiography.

G/R.194 GONAD DOSES IN RADIODIAGNOSIS

Summarizes the systematic study on the gonad dose due to diagnostic examination by means of X-rays.

G/R.211 ETUDE DE LA DOSE GONADE, LORS DES EXAMENS RADIO-PHOTOGRAPHIQUES SYSTEMATIQUES. NOTE PRELIMINAIRE CONCERNANT EXCLUSIVEMENT L'IRRADIATION DES GONADES MALES.

Measurement of the gonad dose resulting in males from systematic standardized X-ray examination of the chest indicate that the exposure is very low. An average of 9 mrem for a period of 30 years is computed. The dose to the lungs is discussed with relation to the increase in frequency of lung cancer.

G/R.212 DETERMINATION DU RAPPORT DOSE-ABSORBEE/DOSE D'EXPOSITION DANS L'OS ET LE MUSELE PAR LA METHODE DES GAZ EQUIVALENTS. PRINCIPE DE LA METHODS ET RESULTATS PRELIMINAIRES

Describes the method for determination of the dose absorbed in various tissues using ionization chambers filled with gas mixtures of equivalent density.

G/R.213 LA RESTAURATION CONSECUTIVE A L'ACTION DES RADIATIONS IONISANTES

The authors first discuss the problem of recovery which they consider hypothetically. They attempt to show that it is a phenomenon which, though appearing very complex at first glance, can be simplified by relating the recovery to a definite effect.

They contribute a series of experiments showing that recovery is a very general phenomenon, common to all living things, and related to the metabolic activity of living matter.

They contribute a new method of experimental analysis which greatly facilitates interpretation of the results. They believe that the study of recovery should be developed on a much larger scale.

Hungary

G/R.25 UNUSUAL RADIOACTIVITY OBSERVED IN THE ATMOSPHERIC PRECIPITATION IN DEBRECEN (HUNGARY) BETWEEN 22 APRIL–31 DECEMBER 1952

Describes methods and discusses results of measurements of total beta activity of fallout at Debrecen, April–December 1952.

India

G/R.32 PROCEDURE USED IN INDIA FOR COLLECTION OF FALLOUT SAMPLES AND SOME DATA ON FALLOUT RECORDED IN 1956

Describes methods for measurements of airborne activity by filtration, and of deposited fallout with daily and monthly collection. The information includes tables giving results.

G/R.33 EXTERNAL RADIATION DOSE RECEIVED BY THE INHABITANTS OF MONOZITE AREAS OF TRAVANCORE-COCHIN, INDIA

Contains results of a survey to measure the radiation level of the Indian state of Travancore. The radiation level due to gamma rays at about 3 feet above the ground level ranges from 6,000 to 100 mrad/year, approximately. The main contributors are thorium and its decay products.

India (Continued)

G/R.166 MEASUREMENTS ON THE RADIATION FIELDS IN THE MONAZITE AREAS OF KERALA IN INDIA

Presents results of measurements in the monazite area with high thorium content. As this area is one of the most densely populated areas in the world, the study of the relation between high level radiation background and eventual biological effect would be of great value.

The average dose is 1500 mrad per year, exceeding 3 times the maximum permissible dose.

International Commission on Radiological Protection and International Commission on Radiological Units and Measurements

G/R.117 EXPOSURE OF MAN TO IONIZING RADIATION ARISING FROM MEDICAL PROCEDURES

Gives a survey of the present exposure of the gonads due to X-ray diagnostic procedures. Some 85% of the diagnostic dose arises from 6 to 7 types of examinations, which are discussed separately. Estimates of the genetically significant dose are given for some countries. It is recommended that the basic studies be extended and that more detailed analysis be obtained through sampling procedures rather than through the systematic recording of the radiation received by every member of the population. Methods for dose reduction are discussed.

Italy

G/R.134 REPORT ON GENETICS 1950–1957—A BRIEF REPORT ON THE RESEARCH WORK DONE IN THE FIELD OF GENETICS IN ITALY

Extensive notes reporting relevant research work in the field of genetics carried out in Italy during the period 1950–1957.

G/R.195 DATA ON RADIOACTIVE FALLOUT COLLECTED IN ITALY (1956, 1957, 1958)

Japan

G/R.4 Report consisting of 8 parts, as follow:

PART 1. RESEARCHES ON THE EFFECTS OF THE H-BOMB EXPLOSION AT BIKINI ATOLL 1954 ON ANIMAL INDUSTRY AND SERICULTURE IN JAPAN

Gives negative results of analysis by absorption method of radioactivity in milk, eggs, and agricultural products following the Bikini explosions of May 1954. Related experimental feedings of animals with radioactive ashes were analyzed chemically.

PART 2. THE RADIOACTIVE CONTAMINATION OF AGRICULTURAL CROPS IN JAPAN

Gives results of soil and crop analyses for total radioactivity before and after the May 1954 Bikini explosions, after subtraction of K^{40} content, and with some radiochemical analysis. Radioactivity after the explosion was detected in soil, crops, and other vegetation which are distributed all over Japan. The possible route of contamination is discussed.

PART 3. A PRELIMINARY REPORT OF RECOMMENDATIONS ON THE MODERN METHODS OF ESTIMATING THE BIOLOGICAL ACTIVITY OF SMALL RADIATION DOSE

Several current hematological findings in Japan are summarized and discussed.

PART 4. THE AIRBORNE RADIOACTIVITY IN JAPAN

Analyses of airborne radioactivity by filter and by electrical precipitator are described and compared. Results of analyses 1954–1956 show poor correlation between peaks of contamination and trajectories of high-level air masses.

PART 5. REPORT ON THE SYSTEMATIC OBSERVATIONS OF THE ATMOSPHERIC RADIOACTIVITY IN JAPAN

Describes methods of collection and analysis of fallout in dust, rain, and snow, and of airborne radioactivity, as used in a wide survey at meteorological stations. Results from April 1954–March 1956 are summarized and discussed and the cumulative depositions of Sr^{90} are calculated.

PART 6. ON THE DISTRIBUTION OF NATURALLY RADIOACTIVE NUCLIDES IN JAPANESE ISLANDS

Surveys of the distribution of naturally radioactive nuclides in Japanese waters and minerals are reviewed and summarized.

PART 7. RADIOCHEMICAL ANALYSIS OF RADIOACTIVE FALLOUT OBSERVED IN JAPAN

Presents methods and results of radiochemical analyses of ash from the fishing boat No. 5 Fukuryu Maru and of rainwater and soil samples in Japan.

PART 8. FISSION PRODUCTS IN WATER AREA AND AQUATIC ORGANISMS

Describes fallout distribution and uptake generally, with special reference to water and aquatic organisms and to the problem of Sr^{90}.

G/R.43 THE EFFECT OF MOMENTARY X-RAY EXPOSURE IN A SMALL DOSE UPON THE PERIPHERAL BLOOD PICTURE

Decrease in lymphocyte number after single 60 mr exposure in humans. Decrease in lymphocyte count varies from 10 to 50%–the maximum drop occurs 30 minutes after irradiation, and may be followed by an increase in lymphocyte count.

G/R.44 HEMATOLOGICAL EFFECTS OF SINGLE EXPOSURE TO SMALL DOSES OF X-RAY

Hematological effects during routine chest examinations. Dosages up to 3 r. Most constantly observed are: increase in neutral red bodies and Demel's granules in lymphocytes and late decrease in mitochondrial index of lymphocytes during the four-hour period following the irradiation. The cytochemical identification of these various granules and their biological significance should be established unequivocally.

G/R.45 MORPHOLOGICAL CHANGES OF PLATELETS IN CHRONIC RADIATION INJURIES

Platelet morphology in chronic irradiation injury in rabbits (chronic 0.1152 or 0.2312), X-ray workers (dosage not evaluated) and persons exposed to atomic bomb within 4 km from epicenter (9 years after the exposure).

Even if platelet count is normal, area index (proportional to average area) is increased markedly, and may remain so 9 years after irradiation and is not necessarily related to low platelet count. Other morphological changes are also shown.

This observation should be repeated by other groups.

G/R.61 CURRENT AND PROPOSED PROGRAMMES OF RESEARCH AND INVESTIGATION RELATED TO RADIATION GENETICS IN JAPAN

A brief survey of current and planned research in Japan relevant to radiation genetics, covering both human surveys and experimental work.

G/R.61 (Add.1) TABLE 1(2) TO ABOVE REPORT: EXPERIMENTAL DATA WITH β RADIATION

G/R.62 RADIOCHEMICAL ANALYSIS OF Sr^{90} AND Cs^{137}

Discusses methods of radiochemical analysis of Sr^{90} and Cs^{137}, including separation of strontium by precipitation and by ion exchange. Experiments for determining the best conditions for ion exchange separations are reported.

G/R.63 REVIEW OF THE RECENT RESEARCHES ON THE BIOLOGICAL EFFECTS OF IONIZING RADIATION IN JAPAN

Contains brief abstracts of 55 papers from the Japanese literature dealing with (1) research on biological indicators of the effects of ionizing radiation in small and large doses, and (2) research on counter measures to alleviate radiation injury. Classical and more modern morphological, histochemical, and biochemical methods of observation were used for the assessment of radiation damage. Most studies were performed on mammals. It is emphasized that it is very difficult to obtain reliable biological indicators of damage by small doses and that hematological methods are still the most suitable in man.

G/R.70 RADIOLOGICAL DATA IN JAPAN

G/R.70 (Corr.1) Correction to above document.

G/R.135 ANALYSIS OF Sr^{90}, CAESIUM-137 AND Pu^{239} IN FALLOUT AND CONTAMINATED MATERIALS

The report gives radiochemical procedures for Sr^{90}, Cs^{137}, and Pu^{239} from air filter ash. The counting equipment is described briefly.

G/R.136 PRIMARY ESTIMATE OF THE DOSE GIVEN TO THE LUNGS BY THE AIRBORNE RADIOACTIVITY ORIGINATED BY THE NUCLEAR BOMB TESTS

The report gives method and results of measurement of airborne radioactivity for Tokyo from 1955-1957. Values are obtained for gross alpha and beta concentrations and radiochemically determined concentrations of Sr^{90} and Pu^{239}. A method for computation of the dose to the lungs is described. The mean dose during 1955-1957 was of the order of magnitude of 10^{-2} rem/year.

G/R.136 (Corr.1) Correction to above report.

G/R.137 A MEASURE OF FUTURE STRONTIUM-90 LEVEL FROM EARTH SURFACE TO HUMAN BONE

Calculation of the future Sr^{90} level is made on the basis of present data on cumulative ground deposit and food contamination.

The cumulative ground deposit (mc/km^2) is calculated assuming that:

1. The total amount of fission products from future tests is known.
2. 20% of airborne Sr^{90} falls to the earth's surface every year.
3. The distribution of fallout is homogeneous.

The metabolism of Sr^{90} through the food channel and food habit factor related to calcium and strontium source are taken into consideration.

The future human skeletonal dose and maximum permissible level of ground deposit are then calculated.

G/R.138 SUPPLEMENTAL REVIEW OF THE RECENT RESEARCHES ON THE ALLEVIATION OF RADIATION HAZARDS

This is an addition to G/R.63 and gives abstracts of new developments of radiobiology in Japan. Work on protection by amino acids, cystamine and some new derivatives of this last compound is reported. Work on the therapeutic effect of a protein diet and of adrenochrome preparation is also reported.

G/R.138 (Corr.1) Correction to above report.

G/R.139 EXPERIMENTAL STUDIES ON THE DEVELOPMENT OF LEUKEMIA IN MICE WITH FREQUENT ADMINISTRATIONS OF SMALL DOSES OF SOME RADIOACTIVE ISOTOPES (P-32, Sr-89, Ce-144)

The development of leukemia is described in three strains of mice in which the disease has not been observed under control conditions. Nine cases of leukemia have been observed among 46 animals surviving 21 weeks and longer following the first of repeated administrations of P^{32} at three dose levels (0.1, 0.3, and 0.5 $\mu c/g$). Latent periods varied with total dose administered. Larger doses were more effective than small doses. The leukemias were primarily of the myaloid type.

Radiostrontium (Sr^{90}) and radio-cerium (Ce^{144}) were much less and practically ineffective in producing this disease in these animals. Sarcoma of bone was found in strontium-treated animals. It is concluded that leukemia is the result of severe damage to the haematopoietic tissues in the bone marrow and lymph nodes. There are many tables and figures, including results of radiochemical analyses of various bones at various intervals following injection.

G/R.139 (Corr.1) Correction to above report.

G/R.140 EXPERIMENTAL STUDIES ON COLLOIDAL RADIOACTIVE CHROMIC PHOSPHATE $CrP^{32}O_4$

Describes morphological observations on the liver of rats which were injected intravenously with various concentrations of colloidal suspensions (particle size 0.1–1.0 micron) of radioactive chromium phosphate ($CrP^{32}O_4$). Even with high doses (7.5 $\mu c/g$) liver injury did not become manifest until 20 days after injection and correspondingly later with lower doses. Changes in the liver are described but not illustrated. They are greater in the liver than in other organs containing reticule-endothelial cells. The lesions are said to resemble those of virus hepatitis. Large doses of chromium phosphate also produce lesions in the bone marrow with concomitant changes in the peripheral blood.

G/R.140 (Corr.1) Correction to above report.

G/R.141 RADIOLOGICAL DATA IN JAPAN II–CONCENTRATIONS OF STRONTIUM 90, CAESIUM 137, Pu-239 AND OTHERS IN VARIOUS MATERIALS ON EARTH'S SURFACE

Contains data on concentration of Sr^{90} in rain water, soil, foodstuffs, and human bone in Japan obtained by radiochemical analysis in some cases and by computation from the total beta activity in other cases. Besides Sr^{90}, data on Cs^{137}, Pu^{239}, Zn^{65}, Fe^{55}, and Cd^{113} are also included.

G/R.141 (Corr.1) Correction to above report.

G/R.161 A SENSITIVE METHOD FOR DETECTING THE EFFECT OF RADIATION UPON THE HUMAN BODY

Discovery of a new extremely sensitive biological indicator of the effect of ionizing radiation. The acute dose of 50 mr and even less results in significant changes of the phosphene threshold of the eye. Approximately linear relationship between the effect and the logarithmas of the dose from 1 mr to 50 mr is derived. Summation of the effect of repeated exposure is found.

G/R.168 AN ENUMERATION OF FUTURE Sr^{90} CONCENTRATION IN FOODS AND BONE

Gives amendments and corrections to the report G/R.137 based upon new available data.

Japan (Continued)

G/R.172 THE ESTIMATION OF THE AMOUNT OF Sr^{90} DEPOSITION AND THE EXTERNAL INFINITE GAMMA DOSE IN JAPAN DUE TO MAN-MADE RADIOACTIVITY

Korea

G/R.18 REPORT CONCERNING THE REQUEST FOR INFORMATION ON NATURAL RADIATION BACKGROUND

Describes counters used for monitoring radiation background and gives results (cpm) from January 1955 to June 1956.

Mexico

G/R.5 FIRST REPORT ON THE STUDIES OF RADIOACTIVE FALLOUT

Gives full description and comparisons of sticky paper and pot methods, preliminary results May – July 1956 for total β activity and intended expansion of programme.

G/R.42 FIRST STUDIES ON RADIOACTIVE FALLOUT

Revised form of G/R.5.

G/R.164 THIRD REPORT ON THE STUDIES ON RADIOACTIVE FALLOUT

Presents fallout data for 13 stations in Mexico covering the period from March to October 1957.

Computes approximate figures for infinite gamma dose and Sr^{90} precipitation.

Gives preliminary results of Sr^{90} and Cs^{137} content in milk.

G/R.187 SUMMARY OF RADIOACTIVE FALLOUT DATA RECORDED IN MEXICO

Netherlands

G/R.59 RADIOACTIVE FALLOUT MEASUREMENTS IN THE NETHERLANDS

Describes methods used for collecting samples of airborne radioactivity and of deposited fallout, and methods of measurement.

Includes tables of results for 1955 and 1956; calculation of gamma doses and quantity of Sr^{90} computed from total activity.

G/R.90 CHEMICAL STEPS INVOLVED IN THE PRODUCTION OF MUTATIONS AND CHROMOSOME ABERRATION BY X-RADIATION AND CERTAIN CHEMICALS IN DROSOPHILA

A survey of comparative studies of X-ray and chemical mutagenesis in *Drosophila,* made in an attempt to throw light on possible intermediate chemical steps in the induction of chromosome breaks or mutations by ionizing radiation.

G/R.110 FOUR REPORTS ON QUANTITATIVE DETERMINATION OF RADIOACTIVITY

G/R.183 REPORT OF THE COMMITTEE OF THE ROYAL NETHERLANDS ACADEMY OF SCIENCES CONCERNING THE DANGERS WHICH MAY ARISE FROM THE DISSEMINATION OF RADIOACTIVE PRODUCTS THROUGH NUCLEAR TEST EXPLOSIONS

Report on the amount of radioactivity, its world-wide spreading and its biological risk as a consequence of test explosions.

G/R.184 RADIOACTIVE FALLOUT MEASUREMENTS IN THE NETHERLANDS UNTIL DECEMBER 31, 1957

G/R.184 (Corr.1) Correction to above report.

New Zealand

G/R.13 NOTE BY NEW ZEALAND

Gives brief notes in reply to the questions contained in individual paragraphs of annexes to letter PO 131/224 of 9 April 1956 (Annexes derived from G/R.10). Other sections describe: measurements of radioactivity (only radon found) collected from air at Wellington by filter and by electrostatic precipitator February 1953 – May 1956, also by an impactor method in 1953 and in rain water on certain dates November 1955 – May 1956; results of measurements of total beta activities of fallout by sticky paper method May – July 1956.

G/R.107 NEW ZEALAND REPORT TO U. N. SCIENTIFIC COMMITTEE ON ATOMIC RADIATION: EFFECTS OF ATOMIC RADIATION MEASURED IN NEW ZEALAND TO 31 JULY 1957

A set of notes on the current status of various programs in New Zealand within the field of interest of the Scientific Committee on the Effects of Atomic Radiation, including preliminary measurement of radioactive fallout, C^{14} activity airborne, natural and artificial radioactivity, and occupational gonad exposures.

G/R.185 LETTER OF DEPARTMENT OF HEALTH, DOMINION X-RAY AND RADIUM LABORATORY, CHRIST CHURCH, NEW ZEALAND

Contains: (1) Description of radiation protection measures in New Zealand; (2) Results of routine monitoring of radiation workers; (3) Preliminary results of statistical study on genetically significant gonad dose from X-ray diagnosis.

Norway

G/R.14 REPORT OF 3 PARTS

Suggests taurine biochemistry and lens opacities as biological indicators for low doses. Gives notes on disposal of small amounts of radioactive wastes. Describes and gives results of analyses by pot method in 1956 of total beta activity due to fallout on ground, in air, in drinking water, and accumulated in snow falls. Includes some analyses for Sr^{90}.

G/R.92 RADIOACTIVE FALLOUT IN NORWAY

Contains information on methods and results of measurements of fallout in Norway.

G/R.106 INFORMATION ON RADIOLOGICAL DATA

Summary tables on radiological data in Norway with an extensive set of data on x-ray and natural radiation exposures.

G/R.106 (Add.1) Correction to above report.

G/R.111 ON THE DEPOSITION OF NUCLEAR BOMB DEBRIS IN RELATION TO AIR CONCENTRATION

Studies the relation between the deposition of fallout and the airborne activity. It appears that in 1956 – 1957 the fallout in the Oslo area was roughly proportional to the product of precipitation and airborne activity at ground level.

G/R.112 RADIOACTIVE FALLOUT IN NORWAY UP TO AUGUST 1957

Gives the results of measurement of fallout materials in air, precipitations, water, and other samples. Measurement of airborne activity at high altitudes are included. Sr^{90} values are computed from total β activity, a small number of samples having been checked by chemical analysis. Samples of water, milk, and urine have been analyzed for I^{131}.

G/R.113 RADIOCHEMICAL ANALYSIS OF FALLOUT IN NORWAY

Describes the methods used in Norway for determination of Sr^{90}, Cs^{137}, and I^{131}, and contains data of Sr^{90} and Cs^{137} activities in water and milk and I^{131} in milk, in the period February – June 1957.

Norway (Continued)

G/R.144 RADIOACTIVE FALLOUT UP TO NOVEMBER 1957

A review is given of the monitoring in Norway of airborne activity and fallout of radioactive dust; also radioactive contamination in drinking water is reported.

Norway and Sweden

G/R.77 RADIOACTIVE FALLOUT OVER THE SCANDINAVIAN PENINSULA BETWEEN JULY AND DECEMBER 1956

In this report, fallout and rain precipitation figures over the Scandinavian peninsula are discussed. Accumulated monthly fallout is reported for the period July–December 1956.

Poland

G/R.118 REPORT ON MEASUREMENTS OF FALLOUT IN POLAND

Continuous measurements of global beta activity of fallout are reported for four stations in Poland.

Romania

G/R.52 ORGANIZATION AND RESULTS IN RADIOBIOLOGICAL RESEARCH WORK IN THE ROMANIAN PEOPLE'S REPUBLIC

Describes the following:

1. and 2. Protective effect of narcosis during irradiation only.

3. After 325 r, up to 11 days narcosis increases biological effects (does not state what criteria of biological effect).

4. Hibernation (25°C) protects. Hibernation between 18° to 25°C enhances effect. Does not state if this is during or after irradiation.

5. Hematological tests for 350 r.

6. Caffeine or aktedron during irradiation enhances effect; caffeine or aktedron after irradiation diminishes effect.

Suggests roentgenotherapy under conditions of protection (narcosis). Gives programme for radiobiology research in 1956–1957.

Sweden

G/R.15 REPORT OF 15 PARTS

The fifteen sections cover: consumption of the doses to the gonads of the population from various sources; thorough survey of natural radioactivity including estimates of weekly dose-rates; measurements of gamma radiation from the human body; measurements of fallout (1953–1956) including total beta activity, gamma ray spectrum, and migration of Sr^{90} into soils, plants, and grazing animals, content of certain isotopes as well as research upon certain related physical quantities; considerations of occupational (medical) exposures. Methods used are extensively described throughout.

G/R.69 DOES THERE EXIST MUTATIONAL ADAPTATION TO CHRONIC IRRADIATION?

G/R.77 RADIOACTIVE FALLOUT OVER THE SCANDINAVIAN PENINSULA BETWEEN JULY AND DECEMBER, 1956

(See annotation under *Norway and Sweden.*)

G/R.79 A SUGGESTED PROCEDURE FOR THE COLLECTION OF RADIOACTIVE FALL-OUT

Proposes new method for evaluation of the external thirty-year dose due to the deposition of gamma-emitting isotopes, based upon a single beta measurement for each sample and one caesium ratio chemical determination in a pooled sample.

A second part of the report describes a collecting procedure using ion exchange resins.

G/R.145 UPTAKE OF STRONTIUM AND CAESIUM BY PLANTS GROWN IN SOILS OF DIFFERENT TEXTURE AND DIFFERENT CALCIUM AND POTASSIUM CONTENT

G/R.146 THE RADIOACTIVE FALLOUT IN SWEDEN UP TO 1/7/57

Additional data to the report G/R.15 for the period up to June 1957 are given. The total activity, accumulated Sr^{90} and Cs^{137} amount and Sr^{90} content in soil are measured.

G/R.147 GAMMA RADIATION IN SOME SWEDISH FOODSTUFFS

Significant increase of radiation in milk, beef, cattle-bone, and vegetables was found during the period 1952–1956. No increase of gamma radiation in children in the corresponding period could be observed.

G/R.148 PROGRESS REPORT ON THE METABOLISM OF FISSION PRODUCTS IN RUMINANTS

The excretion of radioactive fission products (Sr^{90} and I^{131}) in milk after oral administration is measured.

G/R.149 A METHOD FOR MONTHLY COLLECTION OF RADIOACTIVE FALLOUT

Describes a collecting procedure using anion and cation exchange resins.

G/R.150 THE COMPUTATION OF INFINITE PLANE 30-YEAR DOSES FROM RADIOACTIVE FALLOUT

Proposes new method for evaluation of the external 30-year dose due to the deposition of gamma emitting isotopes, based upon a single beta measurement for each sample and one Cs^{137} ratio chemical determination in a pooled sample.

G/R.151 THE CONTROL OF IRRADIATION OF POPULATIONS FROM NATURAL AND ARTIFICIAL SOURCES

Describes an automatic system for continuous indication and recording of very low radiation level; suggests the use of such instrument for public control purposes.

G/R.173 TRANSFER OF STRONTIUM-90 FROM MOTHER TO FOETUS AT VARIOUS STAGES OF GESTATION IN MICE

Shows that no significant fixation of Sr^{90} by the foetus can be detected before the 15th day of gestation. The increase of radioactivity corresponds with the intensity of ossification processes.

G/R.174 THE RECOVERY PHENOMENON AFTER IRRADIATION IN DROSOPHILA MELANOGASTER

1. Recovery or differential sensitivity to X-rays.

Experimental results: lower rate of chromosome aberrations induced by X-ray if irradiated in anoxia in comparison with irradiation in air. Supports the hypothesis of recovery.

G/R.174 (Add.1) THE RECOVERY PHENOMENON AFTER IRRADIATION IN DROSOPHILA MELANOGASTER

Indicates that both the spontaneous recovery and the differential sensitivity in sperm's genesis in *Drosophila* are responsible for the changes in the rate of chromosome breaks under conditions of irradiation.

G/R.174 (Add.2) THE RECOVERY PHENOMENON AFTER IRRADIATION IN DROSOPHILA MELANOGASTER

Chromosomes breakage *per se* or their rejoining by recovery seems to have no genetic consequences.

G/R.175 REPORTS ON SCIENTIFIC OBSERVATIONS AND EXPERIMENTS RELEVANT TO THE EFFECTS OF IONIZING RADIATION UPON MAN AND HIS ENVIRONMENT ALREADY UNDER WAY IN SWEDEN

G/R.175 (Add.1) REPORT ON EXPERIMENTS ON THE INFLUENCE OF SELECTION PRESSURE ON IRRADIATED POPULATIONS OF DROSOPHILA MELANOGASTER

Attempts to determine the influence of high selection pressure in a population on the spread of radiation-induced genetic changes. No results are as yet available.

G/R.175 (Add.2) STUDIES ON THE MUTAGENIC EFFECT OF X-RAYS

Summarizes the results of the work on radiation-induced chromosome breakage under various conditions.

G/R.175 (Add.3) DOES THERE EXIST MUTATIONAL ADAPTATION TO CHRONIC IRRADIATION?

The results do not confirm the assumption that under the increased radiation-background mutational adaptations occur due to incorporation in the population of mutational isoalleles with lower mutability.

G/R.175 (Add.4) SOME RESULTS AND PREVIEWS OF RESEARCH IN SWEDEN. RELEVANT TO HUMAN RADIATION GENETICS

Summarizes the present state of knowledge and recommends: (1) Large scale international investigation of genetic consequences in females who have been controlled by means of X-rays due to congenital dislocation of the hip. (2) The study of genetic effects of radiation on human cell cultures.

G/R.175 (Add.5) SUMMARY OF PAPERS OF LARS EHRENBERG AND COWORKERS WITH REGARDS TO THE QUESTIONS OF THE U. N. RADIATION COMMITTEE

Summary of papers of L. Ehrenberg and coworkers on genetic effects of radiation.

G/R.175 (Add.6) STUDIES ON THE EFFECTS OF IRRADIATION ON PLANT MATERIAL CARRIED OUT DURING RECENT YEARS AT THE INSTITUTE FOR PHYSIOLOGIC BOTANY OF UPPSALA UNIVERSITY

G/R.175 (Add.7) SWEDISH MUTATION RESEARCH IN PLANTS

G/R.175 (Add.8) DR. GUNNAR OSTERGREN AND CO-WORKERS

Study on experimentally induced chromosome fragmentation.

G/R.175 (Add.9) INVESTIGATIONS CARRIED OUT BY DR. C. A. LARSON (HUMAN GENETICS)

G/R.176 SOME NOTES ON SKIN DOSES AND BONE MARROW DOSES IN MASS MINIATURE RADIOGRAPHY

G/R.177 INVESTIGATIONS INTO THE HEALTH AND BLOOD PICTURE OF SWEDISH WOMEN LIVING IN HOUSES REPRESENTING DIFFERENT LEVELS OF IONIZING RADIATION

No difference was found either in general health-state or in blood picture among the various groups of individuals (over 2000 women) living in different types of dwelling.

G/R.178 11 OTHER HAEMOPOIETIC FUNCTIONS: READ-OFF METHODS IN RADIO-HAEMATOLOGICAL CONTROL

Proposes a statistical method of evaluating total white-cells count as a control test of radiation damage.

Sweden (Continued)

G/R.181 BONE AND RADIOSTRONTIUM

The local radiation dose to the bone tissue and to the bone marrow after administration of bone-seeking isotopes is discussed. The figures are compared with the maximum permissible body burden.

G/R.182 RADIATION DOSES TO THE GONADS OF PATIENTS IN SWEDISH ROENTGEN DIAGNOSTICS. SUMMARY OF STUDIES ON MAGNITUDE AND VARIATION OF THE GONAD DOSES TOGETHER WITH DOSE REDUCING MEASURES

Switzerland

G/R.27 LETTER FROM THE "SERVICE FÉDÉRAL DE L'HYGIÈNE PUBLICQUE," BERN

Gives brief description of works on studies of atomic radiations conducted in Switzerland.

Union of Soviet Socialist Republics

G/R.37 ON THE METHODS OF INDICATING THE CHANGES PRODUCED IN THE ORGANISM BY SMALL DOSES OF IONIZING RADIATION

Gives an enumeration of many methods which might be used as tests for small dosages; but these are based on certain symptoms which have not yet been worked out to give a quantitative response; i.e., vegetative-visceral symptoms, nervous symptoms (like the increase in threshold of gustatory and olfactory sensitivity, etc.), skin vascular reactions, electroencephalogram.

Blood symptoms are also described (alterations of thrombocytes and lack of a leucocytosis response to the injection of Vit. B-12).

Certain "immunological" symptoms are quoted, such as the bactericidal properties of saliva and of skin.

G/R.39 CONTENT OF NATURAL RADIOACTIVE SUBSTANCES IN THE ATMOSPHERE AND IN WATER IN THE TERRITORY OF THE UNION OF SOVIET SOCIALIST REPUBLICS

Studies content of natural radioactive substances in the atmosphere and in waters; geochemical considerations on mechanism of contamination of waters and description of radiohydrogeological methods. Gives methods of measurement of airborne activity and results, and includes tables giving content of natural radioactive products in air and waters.

G/R.40 STUDY OF THE ATMOSPHERIC CONTENT OF STRONTIUM-90 AND OTHER LONG-LIVED FISSION PRODUCTS

Gives measurements of airborne fission products (Sr^{90}, Cs^{137}, Ce^{144}, and Ru^{106}); methods for collection of samples and of their radiochemical analysis; results and comments.

G/R.41 ON THE BEHAVIOR OF RADIOACTIVE FISSION PRODUCTS IN SOILS, THEIR ABSORPTION BY PLANTS AND THEIR ACCUMULATION IN CROPS

Report made in two parts

Part I. Experiments of absorption and desorption by soil of fission products and especially of isotopes such as $Sr^{90} + Y^{90}$, Cs^{137}, $Zr^{95} + Nb^{95}$ and $Ru^{106} + Rh^{106}$ are described. Theoretical analysis is also described.

It was observed that $Sr^{90} + Y^{90}$ is absorbed through ion exchange reaction, and is completely or almost completely displaced from the absorbed state under the action of a neutral salt such as $CaCl_2$. Radioactive equilibrium between Sr^{90} and Y^{90} is destroyed during the interaction with soil.

Displacement of absorbed radiocesium is greatly affected by the potassium ions, but not highly affected by $NaNO_3$ or $CaCl_2$ compared with $Sr^{90} + Y^{90}$. Zirconium and ruthenium absorbed by soil exhibit a much lower susceptibility to desorption into neutral salt solution, though their absorption is less complete. The disturbance of the equilibrium occurs also by absorption or desorption.

Part II. The results of experiments on uptake of fission products by several agricultural plants are described. In water culture, the bulk of radioactive isotopes of cesium and strontium is held in the above-ground organ of plant, while Zr, Rh^{106}, and Ce are mainly retained in the root system. Sr and Cs are likely to accumulate in reproductive organs of plants in larger quantities than Zr, Ru, and Ce. The plant uptake is affected by the concentration of hydrogen ions in the solution. Plants' uptake of fission products from soils is considerably smaller than from aqueous solution, and cesium was found to be less absorbable from soil, compared with other isotopes, while cesium is among the fission products most strongly absorbed by plants in water culture. These facts can be explained by the absorptive and desorptive capacity of the isotopes of the soil. The properties of soil as well as the application of lime, potassium or mineral fertilizers greatly affect the plant uptake. When a solution of fission products was applied to leaves of a plant, radioisotopes were observed to pass to other organs. Radiocesium was the most transmovable among the isotopes tested.

G/R.47 PRELIMINARY DATA ON THE EFFECTS OF ATOMIC BOMB EXPLOSIONS ON THE CONCENTRATION OF ARTIFICIAL RADIOACTIVITY IN THE LOWER LEVELS OF THE ATMOSPHERE AND IN THE SOIL

Contains description of methods of measurement of radioactive products in the air at ground level and high altitude and gives results of observations.

Also contains the following conclusions:

1. The existing technique for detecting the presence of artificial radioactivity in the lower atmosphere and the technique for determining the integral activity for aerosols deposited on the earth's surface makes it possible to estimate the level of contamination of the soil by radiostrontium (Sr^{90}).

2. The accumulation of radiostrontium in the soil in various areas of USSR territory is attributable partly to the explosion of atomic bombs in USA and partly to explosions set off in USSR. The lower limit of activity of the Sr^{90} which has accumulated in the past two years (1954–1955) is as high as about 30 millicuries per km^2 in certain towns (cf., for example, Adler).

3. Since radiostrontium is readily caught up in the biological cycle, suitable projects must be put in hand to determine the permissible levels of contamination of the soil with radiostrontium (Sr^{90}) and other biologically dangerous isotopes.

G/R.48 PROGRAMME OF SCIENTIFIC RESEARCH ON THE EFFECTS OF IONIZING RADIATIONS ON THE HEALTH OF PRESENT AND FUTURE GENERATIONS

Describes a programme of research intending to study the effects of radiation at dosages 1 or 2 orders of magnitude above background intensity, of contamination of the air and soil and life in areas of high natural radioactivity.

G/R.49 SUMMARIES OF PAPERS PRESENTED AT THE CONFERENCE ON THE REMOTE CONSEQUENCES OF INJURIES CAUSED BY THE ACTION OF IONIZING RADIATION

Mostly concerned with effects of various radionuclides and external radiation on different mammalian populations (hematology, carcinogenesis, fertility mostly studied). Twenty-two papers are summarized.

G/R.50 CONTRIBUTIONS TO THE STUDY OF THE METABOLISM OF CESIUM, STRONTIUM, AND A MIXTURE OF BETA EMITTERS IN COWS

The metabolism of Cs^{137}, $Sr^{89,90}$ and a number of mixed beta emitters has been studied in cows (milk, urine, feces, tissues).

Strontium: about 10% given is absorbed in intestine and 1.45% is retained in bones, and twenty times less in the soft tissues. The rest is excreted by milk or urine.

Cesium: about 25% given is absorbed in intestine—one fifth of this is retained in muscle and less than one tenth of this amount in other organs or skeleton; the rest is eliminated in the milk or urine.

G/R.53 Report consists of two articles

1. THE EFFECTS OF IONIZING RADIATIONS ON THE ELECTRICAL ACTIVITY OF THE BRAIN

(a) Grigorev's research work states: γ rays depress electrical action of human brain. Does not confirm Eldrid-Trowbridge, who do not find effect on monkey.

(b) Describes effects of β rays of P^{32} (0.05 mc/kg up to 1 mc/kg) on electroencephalogram of dogs. This was followed by radiation sickness (if dose >0.5 mc/kg) and hematological effects. A special implantation method of the electrodes is used. Injection of 0.09 mc/kg gives change in amplitude 5 minutes after (reduction in amplitude). Id. when 0.5 mc—lowering of electrical activity lasts for several days. For dosages above 0.1 mc, part of the repression of brain activity is probably a result of the radiation sickness induced by such high dosages.

2. ON THE BETA RADIATION ACTIVITY OF HUMAN BLOOD

Report on radioactivity of human blood: 100 cc of normal blood have a radioactivity of 1.7 to 3.64 10^{-10} curies (due to K^{40}). Permits determination of K content of whole blood. Same values are found in different pathological conditions. No data on people working with radioactive material.

G/R.160 DRAFT OF CHAPTER F PREPARED BY THE DELEGATION OF THE U.S.S.R. TO THE SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION

G/R.163 DATA ON THE RADIOACTIVE STRONTIUM FALLOUT ON THE TERRITORY OF THE U.S.S.R. TO THE END OF 1955

G/R.196 DRAFT CHAPTER ON "GENETIC EFFECTS OF RADIATION" FOR THE REPORT TO BE TRANSMITTED BY THE SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION TO THE GENERAL ASSEMBLY IN 1958

G/R.197 DRAFT CHAPTER ON "CONCLUSIONS AND RECOMMENDATIONS" FOR THE REPORT TO BE TRANSMITTED BY THE SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION TO THE GENERAL ASSEMBLY IN 1958

G/R.198 CONTAMINATION OF THE BIOSPHERE IN THE VICINITY OF LENINGRAD BY THE PRODUCTS OF NUCLEAR EXPLOSIONS

Contains the description of methods used for monitoring the fallout deposition. Results for the period 1953—1957 are given. Data on specific activity of water from the river Neva, the sea, and the water supply system are also included. Accumulated radioactivity on the ground and external dose from radioactive deposit are then computed. Special attention is given to the contamination of the biosphere by Sr^{90}. Data are based on Hunter and Ballou's calculation.

G/R.199 STUDY OF THE STRONTIUM-90 CONTENT OF THE ATMOSPHERE, SOIL, FOODSTUFFS, AND HUMAN BONES IN THE USSR

The Sr^{90} content of the air, soil, milk, and cereals in various districts of the USSR was determined by radiochemical analysis. Preliminary results on the Sr^{90} content in bones from children in the Moscow district give the average value of 2, 3 S.U. in the second half of 1957. A few data on Cs^{137} concentration in the air are attached.

G/R.200 UPTAKE OF RADIOACTIVE STRONTIUM BY PLANTS AND ITS ACCUMULATION IN VARIOUS AGRICULTURAL CROPS

Detailed analysis of Sr^{90} uptake by plants in relation to their biological characteristic (plant species, vegetative period) and the properties of the soil.

Both factors can influence to a large extent the incorporation of Sr^{90} during the biological cycle.

G/R.201 SOME RESULTS OF A STUDY OF THE BONE SYSTEM AFTER INJURY BY RADIOACTIVE STRONTIUM

Reviews the experimental results obtained in the studies on the effect of bone-seeking radioisotopes. The progressive pathological changes leading to the development of bone tumors are described. The disturbances in the osteogenetic processes during the initial stages after contamination are marked pretumorous changes; their histological characteristic and their pathogenetic significance are discussed.

G/R.202 BLASTOMEGENIC EFFECTS OF STRONTIUM-90

Summarizes and evaluates the results so far published on the cancerogenic effect of Sr^{90} in bone. In particular, the minimum and optimum tumor-producing doses, the latent period and the distribution of Sr^{90} are discussed. The connection between the blastomogenic effect and the development of leukemia is briefly mentioned.

G/R.203 THE RADIATION HAZARDS OF EXPLOSIONS OF PURE HYDROGEN AND ORDINARY ATOMIC BOMBS

Compares the hazards of the long-lived radioactive substances dispersed throughout the world after the explosion of a fission and a pure fusion bomb. Radiation doses to the gonads and bones are calculated and the number of persons affected (hereditary diseases and leukemia) then computed. The conclusion is drawn that a pure fusion bomb cannot be regarded as less dangerous to mankind than a fission bomb.

G/R.204 TOWARDS AN ASSESSMENT OF THE HAZARD FROM RADIOACTIVE FALLOUT

An attempt to assess the various forms of hazard involved in the contamination of the earth's surface with long-lived radioactive fission products. The particular importance of Sr^{90} is stressed. Effects of small doses of radiation and the concept of maximum permissible dose are discussed.

G/R.205 NATURE OF THE INITIAL EFFECT OF RADIATION ON THE HEREDITARY STRUCTURES

A survey of the present knowledge of the nature of the primary mechanisms through which ionizing radiation damages the hereditary structures.

G/R.206 RADIATION AND HUMAN HEREDITARY

Emphasizes the importance of the basic scientific principles of radiation genetics for the assessment of radiation-induced changes in human heredity. The natural mutation rate for various hereditary abnormalities is compared with the observations so far available on irradiated human population. The comparison of natural and induced mutagenesis both in experimental organisms and in men is the basis on which the doubling dose for man was estimated as approximately 10 r. The lack of exact knowledge and the urgent need for it is stressed.

G/R.207 THE EFFECT OF RADIATION ON THE HISTOLOGICAL STRUCTURE OF MONKEY TESTES

Presents the results of histological analysis of monkey testes two years after exposure to a dose of 150–450 r. While the recovery process proceeds rapidly and is apparently complete in animals irradiated after the attainment of sexual

Union of Soviet Socialist Republics (Continued)

maturity, harmful disturbances have been found in young animals even two years after exposure.

G/R.208 THE CYTOGENETIC EFFECTS OF RADIATION EXPOSURE ON SPERMATOGENESIS IN MONKEYS

Presents the results of cytological analysis of monkey testes two years after exposure to a dose of 150–450 r. Extensive damage to the spermatogenesis was found. The frequency of chromosome rearrangements in mammals considerably exceeds that in *Drosophila* after exposure to the same dose, being 65% and 1.6% after 500 r respectively.

Union of South Africa

G/R.6 PRELIMINARY REPORT ON RADIOACTIVE FALLOUT

The preliminary result of the measurement of total β activity of fallout by porcelain dish method is described and results are given for January–June 1956. Sr^{90} deposition was estimated by chemical analysis.

United Arab Republic

G/R.191 RADIOACTIVE FALLOUT IN EGYPT: DECEMBER, 1956–FEBRUARY 1957

G/R.192 RADIOACTIVE FALLOUT IN EGYPT: MARCH–DECEMBER 1957

G/R.193 SOME SOMATIC CHANGES OBSERVED IN CULEX MOLESTUS FORSKAL 1775

Shows differences in the uptake of P^{32} in dependence upon the development stage and sex. The explanation of sex-difference is discussed.

UNESCO/FAO/WHO

G/R.162 UNESCO/FAO/WHO REPORT ON SEA AND OCEAN DISPOSAL OF RADIOACTIVE WASTES, INCLUDING APPENDICES A, B, AND C

Summarizes contributions made by different authorities.

Appendix A. R. Revelle and M. B. Schaefer. General considerations concerning the ocean as a receptacle for artificially radioactive materials.

Contains general account of the processes in the oceans and indicates the necessity of research on certain basic problems which would enable prediction of the consequences of the disposal of large quantities of radioactive material at sea.

Recommends measures of an international character in order to assure safe liquidation of atomic wastes.

Appendix B. Report prepared by FAO and WHO. Discusses the questions:

1. The geochemical cycle of various elements between the water and the sediments.

2. The affinities of the various species of organisms in the oceans for different elements which have radioactive isotopes.

3. The possible rate and distance of vertical and horizontal transport of radioactive isotopes by marine organisms.

4. The distribution, abundance, and rate of growth of the populations in the oceans.

Appendix C. Abstracts of eight other contributions to the report on sea and ocean disposal of radioactive wastes.

United Kingdom

G/R.2 THE HAZARDS TO MAN OF NUCLEAR AND ALLIED RADIATIONS

General report covers both somatic and genetic hazards associated with radiation, present and foreseeable levels of exposure, and an assessment of the hazards in terms of associated actual and permissible levels.

G/R.20 THE RADIOLOGICAL DOSE TO PERSONS IN THE UNITED KINGDOM DUE TO DEBRIS FROM NUCLEAR TEST EXPLOSIONS PRIOR TO JANUARY 1956

Summarizes measurements of total beta activity and Sr^{90} content of fallout at ground stations, in rain water and in the air over the United Kingdom during 1952–1955. Includes calculations of time-integrated gamma ray doses.

G/R.30 RADIOSTRONTIUM FALLOUT IN BIOLOGICAL MATERIALS IN BRITAIN

Describes methods for determination of Sr^{90} in soils and material of the biological cycle; gives results of measurement effected in England up to Spring 1956.

G/R.51 THE GENETICALLY SIGNIFICANT RADIATION DOSE FROM THE DIAGNOSTIC USE OF X-RAYS IN ENGLAND AND WALES–A PRELIMINARY SURVEY

Contains an analysis of number of X-ray diagnostic examinations performed per annum in England and Wales, and a subdivision obtained from five selected hospitals into types of examinations, and into age and sex of the patients examined. In addition, an assessment is made of the minimum dose received by the gonads in each type of examination, and the probability of reproduction as a function of age. The results show that it is unlikely that the genetically significant radiation dose received by the population of England and Wales from X-ray diagnosis amounts to less than 22% of that received from natural sources and it may well be several times greater than this figure. Most of this radiation is received in a few types of examinations, undergone by relatively few patients, and by foetal gonads in examinations during pregnancy.

G/R.60 GENETIC RESEARCH IN THE UNITED KINGDOM

Relevant programmes of genetic research in the United Kingdom and their investigators concerned are listed under the headings.

(i) fundamental research upon mechanisms
(ii) population structure
(iii) quantitative data on human mutation

G/R.60 (Add.1) SUGGESTIONS FOR RESEARCH IN RADIATION GENETICS

General considerations are reviewed and a list of suggested programmes of research in the fields of (i) to (iii) is appended.

G/R.100 THE DETERMINATION OF LONG-LIVED FALLOUT IN RAIN WATER

Describes radiochemical procedures for the determination of Sr^{89}, Sr^{90}, Cs^{137}, and Ce^{144} activities in the rain water.

G/R.103 MODIFICATION OF IMMUNOLOGICAL PHENOMENA AND PATHOGENIC ACTION OF INFECTIOUS AGENTS AFTER IRRADIATION OF THE HOST

Evidence is given that whole body irradiation before the repeated injection of antigen both diminishes the peak-concentration of antibody and delays in time the appearance of the peak. The lowest efficient dose was 25 r. The tolerance of heterogeneous skin grafts or bone marrow cells has been also shown after irradiation; the duration of inhibition of immune response is proportional to dose received.

G/R.104 SOME DATA, ESTIMATES, AND REFLECTIONS ON CONGENITAL AND HEREDITARY ANOMALIES IN THE POPULATION OF NORTHERN IRELAND

Presents an extremely detailed and thorough medicogenetic survey of the population of Northern Ireland using data accumulated over a number of years, together with very pertinent analyses of the data, the problem of genetic disability and its relation to radiation effects.

G/R.105 LEUKEMIA AND APLASTIC ANEMIA IN PATIENTS IRRADIATED FOR ANKYLOSING SPONDYLITIS

The incidence of leukemia and of aplastic anemia was investigated in patients treated in Britain for ankylosing spondylitis by means of ionizing radiations during the years 1935–1954.

Relationship between radiation dose and incidence of leukemia was evaluated. The answers suggest the adoption of working hypothesis that for low doses the incidence of leukemia bears a simple proportional relationship to the dose of radiation, and that there is no threshold dose for the induction of the disease. The dose to the whole bone marrow which would have doubled the expected incidence of leukemia may lie within 30 to 50 r for irradiation with X-rays.

G/R.114 THE RELATIVE HAZARDS OF STRONTIUM-90 AND RADIUM-226

Methods for calculations of the doses received by soft tissue cavities in bone containing Sr^{90} and Ra^{226} are presented. Non-uniformity factors are given for the dose from Sr^{90}. Calculation of the maximum permissible body burden for radium on the basis of a given maximum permissible dose-rate to bone gives a wide range of values, depending on the assumptions made. In the case of radiostrontium, the range of possible values is less. It is suggested that radium be no longer taken as the basis for the calculation of maximum permissible body burden of Sr^{90}.

G/R.115 SHORTENING OF LIFE BY CHRONIC IRRADIATION: THE EXPERIMENTAL FACTS

A survey of all published experimental results relating to shortening of life-span of mice due to chronic irradiation.

The comparison of effects between gamma-rays of Co^{60} and fast neutrons is made; the R.B.E. factor used for fast neutrons was 13.

A good agreement of experimental results has been found indicating that chronic irradiation both with gamma-rays and neutrons shortens the life of mice in a reproducible manner. No statistically significant data were found below the weekly dose of 10 r.

The possibility of extrapolation and the possible dose-effect relationship is discussed.

G/R.126 RADIOSTRONTIUM IN SOIL, GRASS, MILK, AND BONE IN U. K. 1956 RESULTS

Results of Sr^{90} analysis of soil, grass, and animal bone for 12 stations in U. K. are given. Human bone specimens obtained in 1956 have also been measured.

G/R.128 IONIZING RADIATION AND THE SOCIALLY HANDICAPPED

Collects available data and calculations concerning the numbers in various classes of handicapped individuals in the U. K. and the relationships of these numbers to genetic factors, mutation rates, and radiation levels.

G/R.132 THE DETERMINATION OF LONG-LIVED FALLOUT IN RAIN WATER

A method is described for the determination of long-lived isotopes in samples of rain water. Some attention is paid to the development of the method, including details of the checks to ensure radiochemical purity of the final sources used for counting.

G/R.143 THE WORLD-WIDE DEPOSITION OF LONG-LIVED FISSION PRODUCTS FROM NUCLEAR TEST EXPLOSIONS

A network of 6 stations in the U.K. and 13 other parts of the world has been set up for rain water collection. Samples are analyzed for Sr^{89}, Sr^{90}, Cs^{137}, and Ce^{144}. This report contains an account of the results obtained so far, and some discussion of the present and future levels of Sr^{90} in U.K. soil.

United Kingdom (Continued)

G/R.152 THE ANALYSIS OF LOW LEVEL GAMMA-RAY ACTIVITY BY SCINTILLATION SPECTROMETRY

The application of gamma-ray spectrometry enables measurement of the gamma-activity of 10^{-11} curies or less.

G/R.167 MEASUREMENTS OF Cs^{137} IN HUMAN BEINGS IN THE UNITED KINGDOM 1956/1957

Describes the method of determining the Cs^{137} content in the human body using gamma-ray spectrometry.

The average present value is 34.0 ÷ 7.6 μc per g potassium.

G/R.170 THE DISPOSAL OF RADIOACTIVE WASTE TO THE SEA DURING 1956 BY THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

Summarizes the discharges of liquid radioactive wastes to the coastal sea from Windscale Works during 1956.

The results of monitoring indicate that the average activity of the samples remains well below the permissible level.

G/R.171 A SUMMARY OF THE BIOLOGICAL INVESTIGATIONS OF THE DISCHARGES OF AQUEOUS RADIOACTIVE WASTE TO THE SEA FROM WINDSCALE WORKS, SELLAFIELD, CUMBERLAND

Summarizes the results of preliminary hydrographic and biological studies and of regular monitoring of the marine environment in the period 1952–1956. About 2,500 curies of radioactive wastes monthly has been discharged during this period. Due to the favorable local conditions, the upper limit for safe liquidation is determined to be more than 45,000 curies per month.

United States of America

G/R.1 THE BIOLOGICAL EFFECTS OF ATOMIC RADIATION

Summarizes general survey in which committees of experts covered the following subjects: genetics; pathology; meteorology; oceanography and fisheries; agriculture and food supplies; disposal and disposers of radioactive wastes.

G/R.7 RADIOACTIVE FALLOUT THROUGH SEPTEMBER 1955

Summarizes analysis of daily samples obtained up to end of September 1955 from 26 stations in United States and 62 elsewhere by gummed film method calibrated against collection in high walled pots (see A/AC.82/INF.1). Cumulative deposition of mixed fission products, integral gamma doses and Sr^{90} deposits are calculated and compared with other findings, including Sr^{90} content of soils and milk.

G/R.11 PATHOLOGIC EFFECTS OF ATOMIC RADIATION

Present knowledge of the pathological (non-hereditary) effects of radiation are surveyed extensively by a committee. Includes separate sections by sub-committees or individual members on: acute and long-term hematological effects; toxicity of internal emitters; acute and chronic effects of radioactive particles on the respiratory tract, delayed effects of ionizing radiations from external sources; effects of radiation on the embryo and foetus; radiation in a disturbed environment; effects of irradiation of the nervous system; radiation effects on endocrine organs.

G/R.21 PROJECT SUNSHINE BULLETIN NO. 12

Presents and discusses results of Sr^{90} analysis since 1 December 1955. Includes Sr^{90} concentration in human and animal bones, animal products, vegetation, soil, precipitation, other water, and air.

G/R.22 SUMMARY OF ANALYTICAL RESULTS FROM THE HASL STRONTIUM PROGRAM TO JUNE 1956

Summarizes the data of research on Sr^{90} conducted by HASL since 1951. Includes the Sr^{90} content in fallout, soil, vegetation, human and animal bones, human urine, milk, cheese, drinking water, and fish. Fallout measurements and samples cover not only United States of America but also several other countries.

G/R.24 THE EFFECT OF EXPOSURE TO THE ATOMIC BOMBS OF PREGNANCY TERMINATION IN HIROSHIMA AND NAGASAKI

Gives full account of survey of pregnancies in Nagasaki and Hiroshima from 1948 to 1954: sex ratio, congenital malformations, still births, birthweights, neo-natal deaths, certain anthropometric measurements at 9 months, and autopsies were compared with parental irradiation histories. No significant correlations were found.

G/R.54 SOME EFFECTS OF IONIZING RADIATION ON HUMAN BEINGS

A report on the Marshallese and Americans accidentally exposed to radiation from fallout and a discussion of radiation injury in the human being. Gives general and clinical symptomatology in relation to the estimated dosage and to internally deposited radionuclides.

G/R.55 BACKGROUND RADIATION – A LITERATURE SEARCH

The results of literature search about background radiations to human beings are described and classified into three categories: (1) cosmic radiation; (2) terrestrial radiation sources; and (3) radiation from internal emitter.

The cosmic radiation is important for the evaluation of natural background, since it is estimated very roughly to contribute about a quarter of total background dosage to the human population at sea level and high latitude. However, its intensity varies with various factors, such as altitude, geomagnetic latitude, barometric pressure, temperature, etc. Facts directly related to biological effects of cosmic rays are also reviewed.

Radiations from naturally occurring radioactive isotopes form another important part of the natural background. The contribution which comes from land is mainly due to K^{40}, Ra^{226}, Th^{232}, and U^{238} and the decay products of the last three nuclides. The radium concentrations in surface water and public water supplies in various districts are tabulated. The atmospheric concentration of Rn and Th is greatly dependent on the locality, atmospheric condition, and degree of ventilation, if indoor.

The population dose due to the natural background radiation is difficult to evaluate in general, because of the statistical nature and varying conditions involved in nations.

G/R.56 OPERATION TROLL

Operation Troll was conducted to survey the radioactivity in sea water and marine life in the Pacific area during the period from February to May 1955. The general conclusions obtained are as follows:

1. Sea water and plankton samples show the existence of widespread low-level activity in the Pacific Ocean. Water activity ranged from 0-579 d/min/liter and plankton from 3-140 d/min/g wet weight.
2. There is some concentration of the activity in the main current streams, such as the North Equatorial Current. The highest activity was off the coast of Luzon, averaging 190 d/min/liter down to 600 m (1 April 1955).
3. Analyses of fish indicate no activity approaching the maximum permissible level for foods. The highest activity in tuna fish was 3.5 d/min/g ash, less than 1 per cent of the permissible level.
4. Measurements of plankton activity offer a sensitive indication of activity in the ocean.

5. Similar operations would be valuable in assessing the activity from future tests and in gathering valuable data for oceanographic studies.

G/R.57 GONADAL DOSE IN ROENTGEN EXAMINATIONS–A LITERATURE SEARCH

Contains results of literature research which show the estimated contribution of gonadal dose by standard medical roentgenographic procedures. Contribution to the gonadal dose of certain examinations, such as examinations of teeth, skull, chest, and extremities, is relatively insignificant, when compared to the case of pelvic and abdominal examinations. It should be noticed that the dose to the foetal gonad is important genetically.

G/R.64 SHORTENING OF LIFE IN THE OFFSPRING OF MALE MICE EXPOSED TO NEUTRON RADIATION FROM AN ATOMIC BOMB

Length of life in the offspring of male mice exposed to moderate doses of acute neutron radiation from a nuclear detonation is shortened by 0.61 days for each rep received by the father over the dose range tested. This figure excludes death before weaning age. The 95% confidence limits are 0.14 and 1.07 days per rep. Extrapolating to a proportional shortening of life in man gives 20 days per rep received by the father as the point estimate and 5 and 35 days as the 95% confidence limits. The offspring were obtained from matings made from 19 to 23 days after irradiation and, therefore, represent the effect of irradiation on germ cells in post-spermatogonial and sensitive stage of gametogenesis. It is probable that irradiation of spermatogonia (the stage that is important from the point of view of human hazards) would give a somewhat smaller effect. However, since the present data show an effect on the offspring which is as large as the shortening of life in the exposed individuals themselves, it seems likely that, even when allowance is made for the conditions of human radiation exposure, shortening of life in the immediate descendents will turn out to be of a magnitude that will warrant serious consideration as a genetic hazard in man.

G/R.65 GAMMA-RAY SENSITIVITY OF SPERMATOGONIA OF THE MOUSE

Relates the depletion of spermatogenic cells to killing of spermatogonia, the repopulation being related to the maturation of surviving cells.

G/R.66 SOME DELAYED EFFECTS OF LOW DOSES OF IONIZING RADIATIONS IN SMALL LABORATORY ANIMALS

A quantitative study of the life span, the incidence of leukemia, tumors (lung, liver, ovary), and lens opacities as a response to low dosages (less than 100 rads).

G/R.67 EFFECTS OF LOW-LEVEL RADIATION (1 TO 3 r) MITOTIC RATE OF GRASSHOPPER NEUROBLASTS

A study of the inhibitions of mitotic rate and of its possible relationship with the alteration of chromosome structure.

G/R.68 EFFECTS OF LOW DOSES OF X-RAYS ON EMBRYONIC DEVELOPMENT IN THE MOUSE

Effects of 25 r applied during different stages of embryonic development on skeletal malformations appearing in the young.

G/R.71 OCCUPATIONAL RADIATION EXPOSURES IN U. S. ATOMIC ENERGY PROJECTS

G/R.72 WORLDWIDE EFFECTS OF ATOMIC WEAPONS

(A comprehensive preliminary report on the Sr^{90} problem up to 1953)

A preliminary report discussing the various aspects of long-range contamination due to the detonation of large numbers of nuclear devices. An improved methodology for assessing the human hazard is developed, and an extensive experimental program is proposed.

G/R.73 MAXIMUM PERMISSIBLE RADIATION EXPOSURES TO MAN

A preliminary statement of the U. S. National Committee on Radiation Protection and Measurement. The recommendations given by the Committee in NBS Handbook 59 have been revised and the maximum permissible dose-levels have been lowered. The concept of "accumulated" dose for occupational conditions differs from the ICRP recommendations of 1956. For the whole population an annual additional exposure of 2.5 times the exposure from natural radiation sources is allowed.

G/R.74 GONADAL DOSE PRODUCED BY THE MEDICAL USE OF X-RAYS

A survey of diagnostic X-ray exposure with an attempt to estimate the genetically significant dose in the United States. The estimate has been made under the assumption that patients undergoing X-ray examinations have a normal child expectancy. The authors have assumed that the genetically significant dose can then be evaluated as approximately equal to the average gonad dose for patients below the age of 30. Using exposure data which are considered fairly representative of American practice they arrive at 130-140 mrem/year and 50 mrem/year as being the most probable and the minimum figure respectively.

G/R.75 SUMMARY OF CURRENT AND PROPOSED PROGRAMS OF RESEARCH IN THE U.S.A. RELATED TO RADIATION GENETICS

A survey by investigator and title of current and proposed programs of research in the U.S.A. related to radiation genetics.

G/R.91 STRONTIUM-90 IN MAN

Radiochemical analysis of Sr^{90} in human bone have been reported. The values are in accord with the predicted levels based on fallout measurements and fractionation through the food chains.

G/R.93 SUMMARY OF ANALYTICAL RESULTS FROM THE HASL STRONTIUM PROGRAM JULY THROUGH DECEMBER 1956

Summarizes data on samples collected by the U. S. A. fallout network since September 1955 up to September 1956. In addition, it summarizes the data of the samples collected for the strontium program during the period July to December 1956.

G/R.94 ENVIRONMENTAL RADON CONCENTRATIONS–AN INTERIM REPORT

Preliminary data showing ambient concentrations of radon in the Metropolitan New York area are presented. An attempt has been made to define the variability of concentration of radon in the general atmosphere with location, time, and weather conditions. Samples have been analyzed from the outdoor air, inside of buildings, and above and below the surface of the ground. Comparisons with the data obtained by other investigators are also shown.

G/R.95 THE RADIUM CONTENT OF SOIL, WATER, FOOD, AND HUMANS–REPORTED VALUES

G/R.96 MARINE BIOLOGY–EFFECTS OF RADIATION–A SELECTED BIBLIOGRAPHY

24 references concerning investigation on the distribution and metabolism of fission products in marine organisms.

G/R.97 SEA DISPOSAL OPERATION

Some atomic energy activities in the United States have been disposing of radioactive wastes at selected ocean disposal sites since as early as 1946. It is the purpose of this report to describe the extent of these disposal operations including a summary of types of packaging used and of places where the wastes are dumped. The status of related oceanographic research (1956) is briefly touched upon.

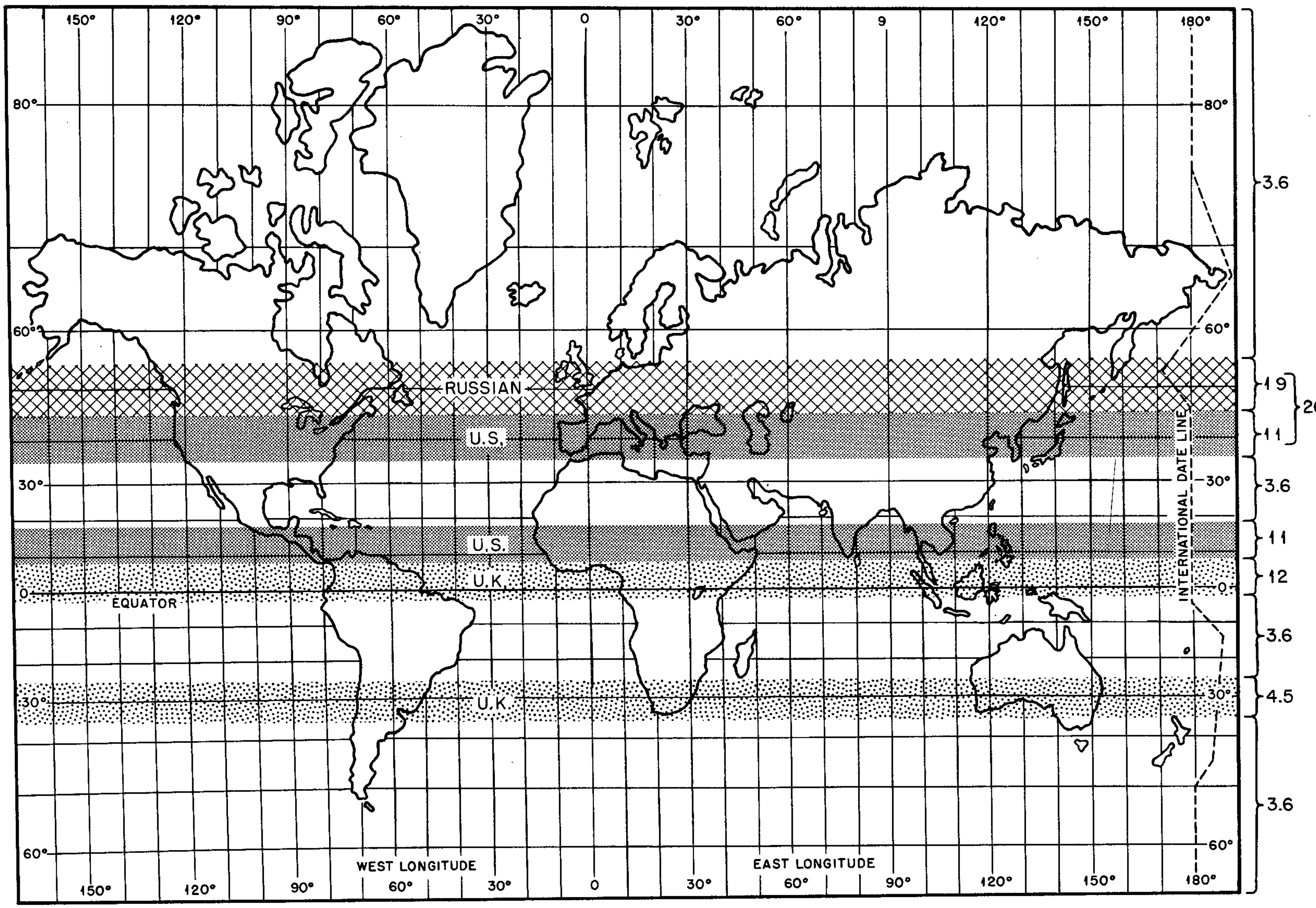

Fig. 4—World fallout map (at end of 1957).

ENTRY OF RADIOACTIVE FALLOUT INTO THE BIOSPHERE AND MAN*

Wright Langham and E. C. Anderson

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Dr. Wright Langham and Dr. E. C. Anderson of the Los Alamos Scientific Laboratory, have prepared a comprehensive review paper discussing world-wide fallout. Because of its excellence as a summary, the Joint Committee on Atomic Energy requested permission to publish the paper last year in the printed hearings on "The Nature of Radioactive Fallout and Its Effects On Man" (p. 1348). The paper is scheduled to appear in Vol. 1, Number 2, 1958, of *Health Physics,* official journal of the Health Physics Society. The title will be, "Potential Hazard of Strontium-90 from Nevada Weapons Testing."

In the light of information appearing in the past year, Dr. Langham and Dr. Anderson updated their paper and presented it before the Swiss Academy of Medical Sciences. We have especially asked for permission to reprint the updated paper here, and wish to acknowledge the permission granted by the authors, the Health Physics Society, and the Swiss Academy. The present paper will appear in the *Bulletin of the Swiss Academy of Medical Sciences* 14, 1958, Basle, Benno Schwabe & Company, as part of the Symposium on the Noxious Effects of Low Level Radiation at Lausanne, Switzerland, March 27–28, 1958.

1 INTRODUCTION

Discussion of the potential hazard of world-wide radioactive fallout from nuclear weapons tests may begin with the consideration of three basic facts.

1. The world population is receiving small exposure to radioactive materials originating from nuclear weapons testing. Fission products from bomb detonations have been and are being deposited over the surface of the earth, increasing the external gamma radiation background and finding their way into the human body through inhalation, direct contamination of food and water, and by transmission along ecological cycles from soils-to-plants-to-animals and to man.

2. Enough radiation, either from an external source or from radioactive isotopes deposited in the body, will produce deleterious effects. These effects may result in an increase in genetic mutations, shortening of life expectancy, and increased incidence of leukemia and other malignant and nonmalignant changes.

3. Radiation exposure is not a new experience for the world population. All life has been exposed to radiation since the beginning. Radiation from cosmic rays, from radioactive min-

*Prepared for the Swiss Academy of Medical Sciences' Symposium on the Noxious Effects of Low Level Radiation, Lausanne, Switzerland, March 27–29, 1958.

erals in the earth's crust and from radium, K^{40}, C^{14}, and thorium deposited in the body constitute this so-called natural background. The amount of natural background radiation is such that persons living to an age of 70 years receive an average total dose of about 7 rem, while their skeletons (as a result of radium and other radioactive materials deposited in the bones) receive an average dose equivalent to about 10 to 12 rem. The natural background dose to some segments of the population may be at least three times the average because of variations in cosmic ray intensity and composition of the earth's crust with geographic location.

The net result of fallout is a small increase in the radiation background to which all life is exposed. The problem of the potential hazard of world-wide fallout then becomes one of trying to ascertain the magnitude and significance of this increase in background dose with regard to its potential risk to man's health and well-being.

Contamination from nuclear weapons testing may be divided on the basis of local and distant (world-wide) fallout.

Local fallout is of primary significance in the event of war in which weapons with a high fission component may be detonated at or below the surface to maximize surface contamination. In this case, fission products of short and intermediate half-life are of major concern since local fallout occurs within a few hours after detonation.

Distant (world-wide) fallout is of significance both with regard to continued weapons testing and in the event of nuclear war. Since months and even years are required for fission products to deposit over the earth's surface, only the long-lived radionuclides are important.

External exposure from environmental deposition of gamma-emitting fission products is of concern primarily because of the potential production of genetic changes. Internal exposure is of significance primarily with regard to the potential production of somatic effects in the tissues in which the various fission products deposit upon entering the body.

This report is restricted mostly to the potential internal hazard of distant (world-wide) fallout, with emphasis on Sr^{90}. Strontium-90 is believed to be the most important radionuclide because of its similarity to calcium (resulting in a high rate of uptake by plants and animals), long physical and biological half-life, and high relative fission yield. These factors lead to high incorporation in the biosphere and a long residence time in bone. General contamination will result in the bones of the population eventually reaching an equilibrium state with Sr^{90} in the biosphere.

2 PRODUCTION OF BIOLOGICALLY IMPORTANT RADIONUCLIDES FROM WEAPONS TESTS

A crude estimate of production of biologically important radionuclides from past nuclear weapons tests would be helpful in assessing the potential hazard of present biospheric contamination and in extrapolating to future levels in the event of continued testing or nuclear war.

Statements during the Subcommittee Hearings of the Joint Committee on Atomic Energy, Congress of the United States[1] assumed a constant nuclear weapons test rate of 10 megatons of fission yield per year, beginning in the spring of 1952. This leads to a total testing by all nations of about 55 megatons of fission yield by mid-1957. The total estimate may be reasonably realistic; however, the assumption of a constant test rate is highly questionable.[2]

One megaton of fission energy release results in the production of about 100,000 curies of Sr^{90},[3] which suggests a total Sr^{90} production of 5.5 megacuries from weapons tests by all nations to mid-1957. From the fission yield curve (thermal neutron fission of U^{235}) and the appropriate decay constants, it is possible to make a crude estimate of the total production of other radionuclides of potential biological importance. Table 1 shows estimates of total production (in terms of megacuries of initial activity) and other pertinent data for the more important intermediate- and long-lived components of fission debris. The values for total yield are crude approximations only because it was necessary to use the fission yield curve for thermal neutron fission of U^{235}, and isotopic abundance varies with the fissionable material and the neutron energy. None of the values, however, are incorrect by more than a factor of about 2.

The total production of Pu^{239} was estimated from the report of Stewart, Crooks, and Fisher,[4] who postulated from analysis of bomb debris that one Pu^{239} atom was formed per

Table 1—POTENTIALLY HAZARDOUS RADIONUCLIDES IN FALLOUT FROM NUCLEAR DETONATIONS

Radionuclide	Type of radiation	Fission* abundance, %	Radiol. half life	Total† production, megacuries	Abs. on ingestion, %	Body MPL, μc
Pu^{239}	α		24,000 yr	0.3	3×10^{-3}	0.037
Sr^{90}	β	5.0	27.7 yr	5.5	30	1.0
Cs^{137}	β,γ	6.2	26.6 yr	7.2	100	54
Pm^{147}	β	2.6	2.64 yr	30	1×10^{-2}	60
Ce^{144}	β,γ	5.3	285 day	200	1×10^{-2}	5
Zr^{95}	β,γ	6.4	65 day	1100	1×10^{-2}	26
Y^{91}	β	5.9	58 day	1150	1×10^{-2}	5
Sr^{89}	β	4.6	51 day	950	30	4
Nb^{95}	β,γ	6.4	35 day	2000	1×10^{-2}	76
Ba^{140}	β,γ	6.0	13 day	5000	5	4
I^{131}	β,γ	2.8	8 day	4000	100	0.7

*Slow neutron fission of U^{235}; abundance in weapon debris is somewhat different.
†Total initial activity in megacuries produced by all weapons tests to mid-1957.

fission by neutron interaction with bomb components. Since 1 kiloton of fission yield is produced by 1.4×10^{23} fissions,[3] each of which results in the production of a Pu^{239} atom, 55 megatons of fission would produce 0.2 megacuries of Pu^{239}. Other isotopes of plutonium, when converted to equivalents of Pu^{239}, bring the total production to about 0.3 megacurie equivalents. The production values given in Table 1 are not a measure of the relative biological importance of the various nuclides, but merely provide some general idea of the relative initial activities produced by all weapons tests through mid-1957. Development of sufficiently sensitive detectors should result eventually in detection of most of these radionuclides in foods and man. Strontium-90 (references 5 and 6), Cs^{137} (reference 7), and I^{131} (reference 8) have been measured quantitatively in the human body, and the presence of Ce^{144} in pooled urine samples has been reported.[9] In addition, Ba^{140} (reference 10) and Sr^{89} (reference 11) have been observed in milk, and other radionuclides have been detected in air and other materials composing man's environment. The extent to which they pose a potential threat to man's health and well-being depend on their rate of production and on their individual physical and biological properties.

3 DISTRIBUTION OF FALLOUT FROM NUCLEAR DETONATIONS

3.1 Postulated Mechanisms of Distribution

Libby[5,12] was first to propose a model explaining fallout and distribution of atomic debris from nuclear weapons detonations. His model is based on three kinds of fallout—local, tropospheric, and stratospheric.

Local fallout is deposited in the immediate environs of the explosion during the first few hours. This debris consists of the large particles from the fireball and includes partially or completely vaporized residues from the soil and structures which are swept into the cloud.

Tropospheric fallout consists of that material injected into the atmosphere below the tropopause which is not coarse enough to fall out locally. This debris is sufficiently fine that it travels great distances, circling the earth from west to east in the general latitude of the explosion, until removed from the atmosphere (with a half-time of 20 to 30 days) by rain, fog, contact with vegetation, and other meteorological and/or physical factors.

Stratospheric fallout is composed of fission products that are carried above the tropopause and can result only from large weapons (of the order of 1 megaton and greater). Libby[13a,b] has postulated that atomic debris, once it is injected above the tropopause, is mixed rapidly throughout the stratosphere and falls back uniformly into the troposphere with a half-time of about 7 years. As it returns to the troposphere, it is deposited over the earth's surface in relation to meteorological conditions. He attributed the higher Sr^{90} soil concentrations in the

United States to meteorological conditions and to local and tropospheric fallout as a result of the proximity of the Nevada Test Site. The generally higher concentrations in the north temperate latitudes were attributed to prevailing meteorological conditions and their effects on tropospheric fallout from tests in the USSR and at the United States Pacific Proving Grounds.

Machta[14] proposed a model of stratospheric fallout which differs in some respects from Libby's. He postulated that stratospheric mixing is slow and that stratospheric distribution of fission products is still nonuniform. He feels that a major portion of the nuclear debris is still in the northern portions of the northern hemisphere, rather than uniformly spread over the entire globe or even uniformly dispersed in the northern hemisphere itself. He feels also that stratospheric movement of the fission products is largely by direct transport from west to east in the general latitude of the point of injection with very slow vertical mixing. Slow polewards circulation of stratospheric air from equatorial regions provides some mixing toward the poles. The higher concentration of fallout in the temperate latitudes is explained on the basis of air exchange between the stratosphere and troposphere through the break in the tropopause in the vicinity of the jet streams. A large part of the higher concentration of Sr^{90} found in the northern part of the United States may result from preferential stratospheric leakage in the vicinity of 30°N to 40°N latitude instead of the proximity of the Nevada Test Site. Qualitatively, both models predict the same general distribution of fallout. Quantitatively, the Machta model predicts a greater degree of nonuniformity of fallout over the earth with higher deposition of fission products in the north and south temperate latitudes from nuclear debris still in the stratospheric reservoir. Figure 1 shows the essential features of the Machta model and the present general world-wide surface distribution pattern of Sr^{90}.

3.2 Average Maximum Surface Deposition Levels

(a) *Present Levels (1956-1957).* A crude indication of latitudinal distribution of the integrated Sr^{90} surface deposition levels as of June 1956, derived from soil data, is shown by the lower curve in Fig. 2. This curve is essentially the same as the one given by Machta[14] except a few points have been added and the peak concentration in the north temperate latitudes is drawn slightly higher to allow some weighting for average Sr^{90} levels in United States soils. These data suggest a level of about 13 mc/sq mile for the north temperate latitudes. No soil data are available yet for mid-1957. Fallout data from pot collections in New York and Pittsburgh, however, showed that cumulative Sr^{90} fallout increased by about 50 per cent from June 1956 to June 1957.[15] The upper curve in Fig. 2 represents estimated latitudinal fallout distribution in June 1957. Some of the increase in New York and Pittsburgh fallout could have been tropospheric contribution from Russian tests, which would result in over-prediction of the Sr^{90} levels in other areas. This and other criticisms, however, seem minor compared to the uncertainty in the primary soil data.

Estimated deposition levels in June 1957 show a total Sr^{90} fallout of about 19 mc/sq mile for the north temperate latitudes, 3 to 4 mc/sq mile for the equatorial regions, and about 5 to 6 mc/sq mile for the south temperate latitudes (Fig. 1). Data from pot collections in the New York area suggest total Sr^{90} deposition levels of about 35 mc/sq mile in the northern United States in mid-1957. The rapid build-up of Sr^{90} in the northern states in the spring of 1957 cannot be attributed to tropospheric fallout from Nevada tests, since Operation Plumbbob had not begun. It may be due to tropospheric fallout from spring test operations in the USSR and to preferential stratospheric fallout from past tests.

The total amount of Sr^{90} deposited over the earth's surface (from both tropospheric and stratospheric fallout) as of mid-1957 can be estimated from the upper curve in Fig. 2 by replotting the data in terms of Sr^{90} deposition/degree times the earth's area/degree. This calculation suggests a world total deposition of 1.64 megacuries, which gives a world average surface level of 8.2 mc/sq mile.

Libby's[12] estimates of Sr^{90} surface deposition levels for the fall of 1956 were 22 mc/sq mile for the northern United States, 15 to 17 mc/sq mile for similar latitudes elsewhere,* and 3 to 4 mc/sq mile for the rest of the world. These values are in good agreement with those

*The north temperate fallout band was indirectly defined as the region between 60°N-10°N latitude. It is assumed that the surface deposition of 16 to 17 mc/sq mile applies to this area.

Fig. 1—Mechanism of distribution of world-wide fallout.

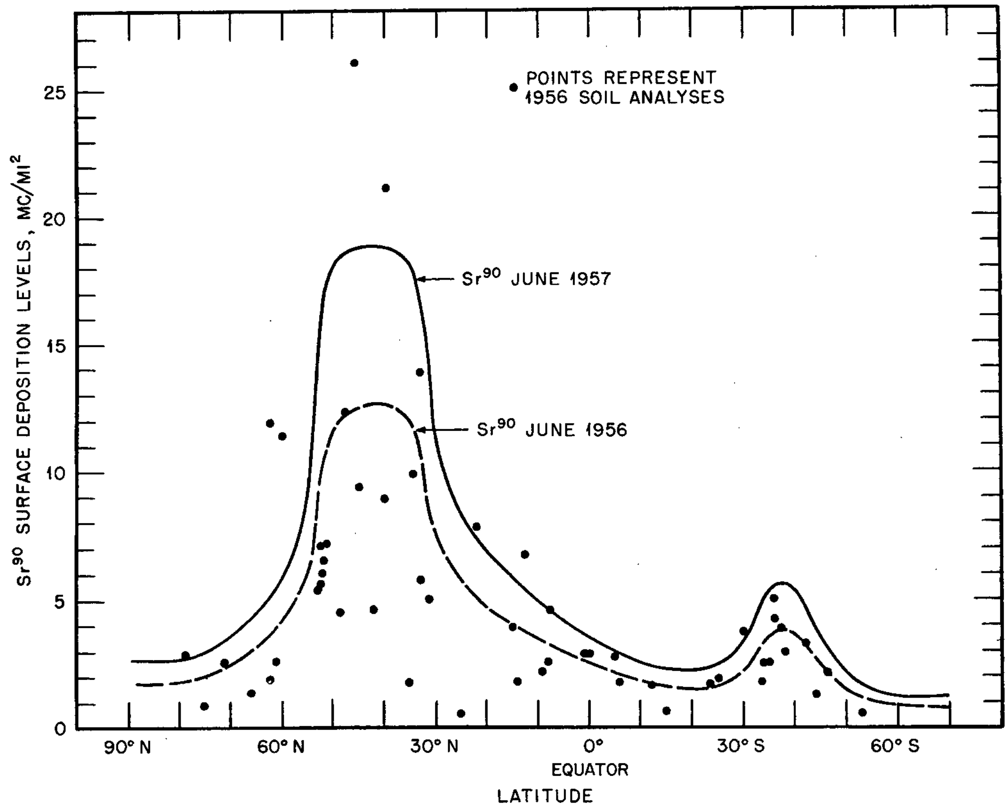

Fig. 2—Surface deposition levels of Sr^{90} from soil analyses.

estimated from the lower curve of Fig. 2. He also estimated the stratospheric reservoir at about 2.4 megacuries (24 megaton equivalents of fission yield). His predictions were based on 1955 soil analyses, his model of tropospheric and stratospheric fallout, and a general knowledge of the megatons of fission devices detonated during the spring and summer of 1956. Using his deposition values and the world Sr^{90} production up to that time, 24 megaton equivalents still in the stratosphere would be possible only provided local fallout from surface detonation of megaton weapons was about 25 per cent.

Values for the world total production (about 5.5 megacuries to mid-1957) and deposition of Sr^{90} may be used to estimate the present magnitude of the stratospheric reservoir. Fallout measurements from United States megaton detonations in the Pacific suggest that 50 ± 17 per cent of fission debris falls out locally. The rest is partitioned between tropospheric and stratospheric fallout. Since the fallout time of tropospheric debris is of the order of 20 to 30 days, the material not accounted for by local fallout plus total world-wide deposition must still be in the stratospheric reservoir. Such a material balance calculation estimates the stratospheric Sr^{90} content at 1.11 ± 0.93 megacurie, or the equivalent of 11.1 ± 9.3 megatons of fission yield. The average is about one-half the value estimated by Libby.[12]

High altitude air sample measurements suggest that considerable specific fractionation of fission debris is occurring. If, however, it is assumed that serious fractionation of Sr^{90}, Pu^{239}, and Cs^{137} does not occur,[12] it is possible to estimate the general distribution of these nuclides in relation to Sr^{90}. Since their radiological half-lives are long compared to the period of testing and the stratospheric storage time, their general distribution should be in direct ratio to their total production relative to that of Sr^{90} (Table 1). On this basis, average maximum surface deposition levels of Pu^{239} and Cs^{137} in the north temperate latitudes (by mid-1957) would be about 1.2 and 25 mc/sq mile, respectively.

Present world-wide distribution of Cs^{137} and Pu^{239}, estimated on the above basis, are compared with Sr^{90} in Table 2.

The estimated levels are general averages only and assume no fractionation and uniform distribution within the respective areas. Actually, this general picture is greatly over-

Table 2—COMPARISON OF WORLD-WIDE DISTRIBUTION OF Sr^{90}, Cs^{137}, AND Pu^{239} FROM NUCLEAR DETONATIONS*

Region	Mid-1957 Sr^{90}, mc/sq mile	Cs^{137}, mc/sq mile	Pu^{239}, mc/sq mile
Northern USA	35	46	2.1
North temperate latitudes	19	25	1.2
South temperate latitudes	5–6	7	0.3
Rest of world	3–4	5	0.2
World average	8	10	0.45
Total surface deposition	1.64 MC	2.1 MC	0.10 MC
Stratospheric reservoir	1.10 MC	1.4 MC	0.06 MC

*Assuming no fractionation.

simplified. Some fractionation is indicated by air sampling data and once fission products are suspended in the troposphere (either directly from the detonation or from stratospheric leakage, regardless of mechanism) meteorological conditions play a major role in their surface distribution. Libby has stressed the importance of rainfall, snow, fog, and mist.[5,12] Within any major area fluctuations in levels of surface deposition may occur which correlate with local meteorological conditions. Machta[14] has guessed that areas as large as milksheds may not have more than 2 to 3 times the average deposition for the latitude. He points out, however, that desert areas where there is practically no rainfall may have almost zero fallout.

(b) *Future Levels (Assuming No More Tests).* Fallout of Sr^{90} and other long-lived radionuclides from the stratospheric reservoir will continue even if weapons tests are stopped. Whether the integrated surface deposition levels continue to build up will depend on whether the rate of stratospheric fallout more than compensates for the rate of decay of material already on the ground.

From the surface deposition levels in Table 2 and the value of 1.1 ± 0.9 megacuries of Sr^{90} for the stratospheric reservoir, estimation of future deposition levels, assuming no more weapons tests, is possible.

If M(t) is the surface deposition level and Q(t) is the stratospheric storage in millicuries per square mile at any time, the rate of change of the surface deposition level is:

$$\frac{dM(t)}{dt} = -\lambda M(t) + kQ(t)$$

where λ is the radioactive decay constant of Sr^{90}, and k is the stratospheric fallout rate constant (assumed to be first order). If $\lambda M(t) = kQ(t)$, dM/dt is zero. In this case, additional stratospheric fallout just compensates for radioactive decay, and M(t) does not change. Such an equilibrium state is transitory, since Q(t) is constantly decreasing (both by decay and by fallout). Loss by radioactive decay in M(t), therefore, soon exceeds gain from Q(t), and M(t) falls. If λM_0 is greater than kQ_0 (where M_0 and Q_0 are the concentrations at t = 0, the time of cessation of tests), the latter situation already exists and the ground level begins to fall when testing stops. Only if λM_0 is less than kQ_0 will additional fallout from the stratosphere exceed the decay of the ground contamination and the surface deposition level continue to rise. If the mean times of decay and fallout are 40 and 10 years, respectively, Q(t) must be at least $\frac{1}{4}$ M(t) for surface deposition to increase.

Future levels, in the event of no more testing, can be estimated if it is assumed that fallout in the future will have the same degree of nonuniformity as in the past. In this case, the effective stratospheric storage ($Q(t)_e$) for a given area is related to the average stratospheric storage ($Q(t)_{av}$) by the equation:

$$Q(t)_e = \frac{M(t)}{M(t)_{av}} Q(t)_{av}$$

where M(t) is the observed ground concentration in the area in question, and $M(t)_{av}$ is the averaged world-wide ground concentration. On the basis of this assumption, the soil levels increase everywhere by the same ratio and reach a maximum about 1963, which is some 10 per cent higher than present levels.

Assuming uniform stratospheric fallout, some areas do not increase since the additional stratospheric fallout is insufficient to compensate for radioactive decay. The time of maximum ground concentration (where it does occur) varies also with location, being about 1966 in the south temperate latitudes and 1969 elsewhere.

Neither method of estimation is strictly correct. The assumption of uniform fallout may underestimate build-up in the northern latitudes, and the assumption of nonuniformity of future fallout according to the past may tend to overestimate build-up in those areas where some of the material deposited in the past came from tropospheric fallout. As stated by Machta,[14] it is hoped that the truth lies somewhere in between. It must also be kept in mind that the stratospheric reservoir may well be 2.4 megacuries as estimated by Libby.[12]

Future Cs^{137} levels, assuming no fission product fractionation and no more tests, will be about 1.3 times higher than the corresponding Sr^{90} levels since their radiological half lives are essentially the same. Pu^{239} levels will continue to rise for several years because of its 24,000-year half life. In this case, λM_0 will be less than kQ_0 until the stratospheric reservoir is essentially depleted. However, surface deposition levels will not increase more than 0.6, which is the ratio of the present total surface deposition to the estimated stratospheric reservoir.

Table 3—PREDICTED AVERAGE MAXIMUM SURFACE DEPOSITION LEVELS OF Sr^{90}, Cs^{137}, AND Pu^{239} (ASSUMING NO MORE WEAPONS TESTS AFTER MID-1957)

Region	Sr^{90}, mc/sq mile*	Cs^{137}, mc/sq mile*	Pu^{239}, mc/sq mile†
Northern USA	39	51	3.3
North temperate latitudes	21	27	2.0
South temperate latitudes	6	8	0.5
Rest of world	4	5	0.3
World average	9	12	0.8

*Maximum will be reached in about 1965.
†Maximum will be reached essentially in about 30 years.

Predicted average maximum surface deposition levels of Sr^{90}, Cs^{137}, and Pu^{239} (assuming nonuniform fallout and cessation of tests) are given in Table 3. Surface deposition levels of other biologically significant isotopes, which all have short half lives compared to the stratospheric storage time and for which λM_0 is already greater than kQ_0, will begin decreasing immediately when weapons tests are stopped.

(c) *Future Levels (With Continued Testing).* If weapons tests continue at a constant rate (in terms of fission yield), the decay of radionuclides in the biosphere will eventually equal the rate of production, and continued testing will result in no further increase in deposition levels. At the present rate of testing (assumed to be 10 megatons of fission per year for the past 5 years), equilibrium Sr^{90} and Cs^{137} levels will be reached in about 100 years. Isotopes with shorter half lives will reach equilibrium sooner. Pu^{239} obviously will continue to increase essentially in proportion to its total production.

Campbell[1c] and Stewart et al.[4] have estimated surface deposition levels of Sr^{90} at equilibrium with a uniform test rate, and their calculations suggest levels about 30 times the present values. Their equations are derived, however, from stratospheric fallout and apply to ground levels due to the stratospheric component only.

Libby[17] estimated surface build-up on the basis of total levels on the ground at t = 5 years and predicted equilibrium levels 11 times the present values. His calculations have been checked by Neuman[18] and others. Libby also assumed that about 30 per cent of the Sr^{90} (over the long period required for equilibrium) would become unavailable to plants and the available equilibrium levels would be only about 8 times the present values.[1] Attempts are being made to obtain actual yearly fission product production rates to refine further predictions of surface levels under continued testing. Until then, an equilibrium build-up factor for Sr^{90} and Cs^{137} of about 10 with a continued average test rate of 10 megatons of fission yield per year seems reasonable. Table 4 shows future average maximum surface deposition levels of Sr^{90}, Cs^{137}, and Pu^{239} calculated, on the above basis, from the data in Table 2.

Table 4—AVERAGE MAXIMUM SURFACE DEPOSITION LEVELS OF Sr^{90}, Cs^{137}, AND Pu^{239} (ASSUMING A CONTINUING TEST RATE OF 10 MEGATONS OF FISSION YIELD PER YEAR)

Region	Sr^{90}, mc/sq mile*	Cs^{137}, mc/sq mile*	Pu^{239}, mc/sq mile†
Northern USA	350	460	40
North temperate latitudes	190	250	24
South temperate latitudes	55	70	6
Rest of world	35	50	3
World average	80	100	11

*At equilibrium in about 100 years.
†In about 100 years, not at equilibrium.

Others have made similar estimates of Sr^{90} surface deposition levels. Libby[19] estimated equilibrium levels for the United States at 400 to 600 mc/sq mile. Neuman[18] estimated a United States deposition level of about 400, and Machta[14] 350 to 850 mc/sq mile.

4 INCORPORATION OF NUCLEAR DEBRIS INTO THE BIOSPHERE AND MAN

Radionuclides from fallout may enter the body through inspiration of the contaminated atmosphere and by ingestion of contaminated food and water.

Stewart et al.[4] estimated the mean Sr^{90} and Pu^{239} concentrations in air at ground level in England during 1952-1955 as 4×10^{-16} and 3×10^{-17} $\mu c/cc$, respectively.* Assuming the ratio of Cs^{137}/Sr^{90} in air is the same as their ratio of total production, the mean Cs^{137} concentration in air during the same period would be 5×10^{-16} $\mu c/cc$. The respective occupational maximum permissible air concentration of Sr^{90}, Pu^{239}, and Cs^{137} recommended by the International Commission on Radiological Protection[21] are 2×10^{-10}, 2×10^{-12}, and 2×10^{-7} $\mu c/cc$. The estimated mean values are 5 to 8 orders of magnitude lower than the maximum permissible air concentrations recommended for the general population.

Since the tropospheric fallout time is 20 to 30 days, the mean air concentration values during 1952-1955 probably approximate equilibrium conditions with the past 5-year rate of biospheric contamination from stratospheric fallout.[20] In this case, continued weapons tests at the past rate should not increase the mean air concentrations greatly. As suggested by Stewart et al.[4] and Bryant et al.,[11] inhalation of nuclear debris is not a major factor in the potential hazards of world-wide fallout.

Comparison of measured and estimated concentrations of the principal long-lived radionuclides in water with the maximum permissible concentrations recommended by the International Commission on Radiological Protection[21] suggest also that ingestion of contaminated drinking water is relatively unimportant.[11]

Ingestion of food contaminated through soil integration and plant uptake of long-lived radionuclides seems to pose the major potential hazard.

When nuclear debris is deposited on the earth's surface and incorporated in the soil, the individual nuclides are taken into plants through the root system according to their individual

*Their calculated value agrees reasonably well with the average measured value of 3×10^{-15} $\mu c/cc$ (for the same period at Washington, D. C.) reported by Martell.[20]

soil-plant relationships. That which settles directly on vegetation may remain as surface contamination or may enter the plant through foliate absorption. When plants are eaten by animals, the radioactivity incorporated in the plants or deposited on their surfaces is absorbed and retained by the animal according to the specific metabolic characteristics of the individual nuclides. When plant and animal products are eaten by man, the radioelements they contain are absorbed and incorporated into his tissues, again in accordance with their individual metabolic properties.

A few of the long-lived radionuclides in nuclear debris will be considered individually, since their accumulation in the soil and ecological transport to man appear to be the major concern.

4.1 Strontium-90

(a) *Ecological Incorporation and Discrimination.* Strontium-90 is chemically and metabolically similar to calcium. Therefore, it is incorporated into the biosphere along the same ecologic chain. It is taken into plants through the root system in relation to available soil calcium and absorbed and deposited in human bone in relation to the Sr^{90}/Ca ratio in the diet.

It is reasonable to assume that strontium may be discriminated against with respect to calcium in passing along the ecological chain. For example, the Sr^{90}/Ca ratio of human bones may be expected to be lower than that of soil. Attempts have been made to determine the over-all Sr^{90}/Ca discrimination ratio in going from soils to human bone by determining the individual discrimination factors (DF) that occur at the various steps along the ecological cycle. Menzel[22] obtained a soil-to-plant discrimination factor (DF_1) of 0.7 for four widely different soil types using both radioactive and stable strontium. Larson[23] and Bowen and Dymond[24] obtained comparable values.

A discrimination factor (DF_2) of 0.13 in going from plants-to-milk has been reported by Alexander et al.[25] and Comar,[26] and the discrimination factors (DF_3) from plants-to-bone and from milk-to-bone (DF_4) have been estimated at 0.25.[27,28]

The over-all discrimination ratio ($OR_{\text{bone-soil}}$) in going from soil-to-human bone via the diet may be estimated from the various discrimination factors and the fraction of dietary calcium derived from dairy products and from other sources. For example, for the United States population the amount of dietary calcium derived from dairy products is estimated at about 80 per cent. The remainder is derived from cereals, vegetables, meats, etc. On the basis of the above generalizations, $(OR_{\text{bone-soil}}) = (0.8 \times DF_1 \times DF_2 \times DF_3) + (0.2 \times DF_1 \times DF_4) = (0.8 \times 0.7 \times 0.13 \times 0.25) + (0.2 \times 0.7 \times 0.25) = 0.05$ and indicates that the average equilibrium concentration of Sr^{90} in bone calcium for the United States population will be about 5 per cent of the concentration in the available soil calcium (Fig. 3).

It should be emphasized that over-all discrimination ratios derived in the above manner apply only to passage along the ecological chain. The ecological discrimination ratio automatically assumes that calcium and strontium are uniformly mixed in soil to the average depth of the plant feeding zone. No allowance is made for direct foliar contamination, for dilution with a greater reservoir of available soil calcium through plowing, for the possibility that it may become less available with time through soil binding and leaching, or for differences in uptake by different plant species.

(b) *Sr^{90} Levels in Bones of the Population.* Present and future average maximum Sr^{90} equilibrium levels in bones of the population can be estimated from the soil-to-bone discrimination ratio, the ratio of milk to other sources of calcium in the diet, and the present and predicted average maximum surface deposition levels given in the previous sections.

Assuming an average of 20 g of available Ca per square foot of soil to a depth of 2.5 in., 1 mc of Sr^{90} per square mile is equivalent to 1.8 $\mu\mu c$ Sr^{90} per gram of available soil calcium. If all of the Sr^{90} is in available form, multiplication of the surface deposition levels by 1.8 gives the Sr^{90} activity per gram of available soil calcium. Multiplication of the specific activity of available soil calcium by the Sr^{90} discrimination ratio should give the average maximum specific activity of calcium laid down in the adult skeleton through exchange and bone remodeling during the period of environmental contamination and the average maximum Sr^{90} concentration in a skeleton at equilibrium with the integrated surface deposition levels.

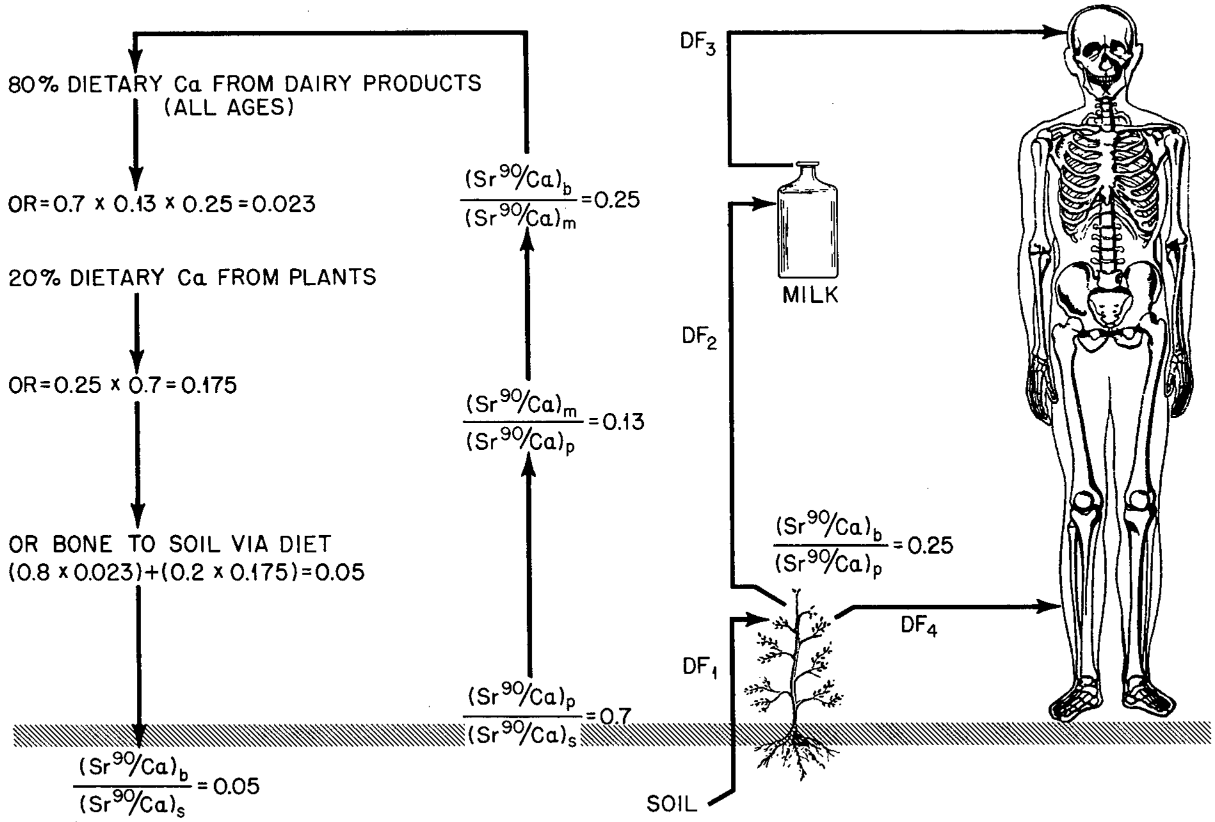

Fig. 3—Ecological discrimination against Sr^{90} with respect to calcium (United States).

The fraction of dietary calcium derived from dairy products varies widely among the various populations. A general expression for the ecological discrimination factor is:

$$(OR_{\text{bone-soil}}) = (M_f \times 0.025) + (R_f \times 0.175)$$

in which M_f and R_f are the fractions of dietary calcium derived from dairy products and from other sources, respectively.

Discrimination ratios of Sr^{90}/Ca for various countries, derived from per capita consumption of principal foodstuffs[29,30] and their average calcium content,[31] are given in Table 5. The over-all discrimination ratio varies from about 0.04 for countries with high milk consumption (New Zealand, Switzerland, Sweden) to about 0.15 for Far Eastern countries that consume little milk. Discrimination ratios were weighted for the population densities of the various countries to give weighted average values of 0.1, 0.06, and 0.12 for the north temperate latitudes, south temperate latitudes, and rest of the world population, respectively. The discrimination ratios for the various areas are only superficially adjusted for differences in population dietary habits and make no allowance for individual variations in calcium metabolism and for the fraction of Sr^{90} entering the food chain through direct fallout on vegetation. They may be conservative, however, because they are derived on the basis of complete availability of the deposited Sr^{90} and on the assumption that all of man's dietary calcium comes from the top 2.5 in. of the soil.

Average maximum Sr^{90} equilibrium bone levels in the world's population postulated from ecological considerations are given in Table 6. These data suggest the average maximum level of Sr^{90} in the bones of the population of the United States would be about 3.1 $\mu\mu c$ per gram of Ca, if they were in ecological equilibrium with the 1957 soil deposition levels. The average of the north temperate population belt would be about the same as the United States because of the lower ratio of milk to cereals in the diet of the heavily populated countries of the Far East. The population weighted world average is only slightly lower than the average for the north temperate latitude, which is not surprising since over 80 per cent of the world's population lives in that region.

Table 5—Sr^{90}/Ca DISCRIMINATION RATIOS FOR VARIOUS COUNTRIES DERIVED FROM PER CAPITA CONSUMPTION OF PRINCIPAL FOODSTUFFS

Country	M_f	R_f	OR
Algeria	0.69	0.31	0.060
Argentina	0.79	0.21	0.055
Australia	0.82	0.18	0.050
Austria	0.85	0.15	0.046
Belgium-Luxembourg	0.75	0.25	0.061
Brazil	0.60	0.40	0.084
Bulgaria	0.54	0.46	0.085
Burma	0.33	0.67	0.125
Canada	0.85	0.15	0.046
Chile	0.67	0.33	0.072
China	0.23	0.77	0.140
Columbia	0.67	0.33	0.072
Cuba	0.67	0.33	0.072
Czechoslovakia	0.71	0.29	0.067
Denmark	0.79	0.21	0.055
Egypt	0.57	0.43	0.088
Finland	0.84	0.16	0.047
France	0.75	0.75	0.061
Germany	0.74	0.26	0.063
Greece	0.63	0.37	0.079
Hungary	0.53	0.47	0.094
India	0.51	0.49	0.097
Indochina	0.16	0.84	0.151
Indonesia	0.11	0.89	0.158
Italy	0.62	0.38	0.081
Ireland	0.75	0.25	0.061
Israel	0.73	0.27	0.064
Japan	0.18	0.82	0.148
Malaya	0.19	0.81	0.146
Mexico	0.56	0.44	0.090
Morocco	0.75	0.25	0.061
Netherlands	0.83	0.17	0.049
New Zealand	0.88	0.12	0.041
Norway	0.86	0.14	0.044
Pakistan	0.72	0.28	0.066
Peru	0.41	0.59	0.113
Philippines	0.18	0.82	0.148
Poland	0.55	0.45	0.091
Portugal	0.30	0.70	0.123
Rhodesia	0.41	0.59	0.113
Rumania	0.59	0.41	0.085
Spain	0.50	0.50	0.099
Sweden	0.87	0.13	0.043
Switzerland	0.87	0.13	0.043
Thailand	0.55	0.45	0.091
Turkey	0.37	0.63	0.119
Union of South Africa	0.71	0.29	0.067
United Kingdom	0.81	0.19	0.052
United States	0.80	0.20	0.053
Uruguay	0.82	0.18	0.050
Venezuela	0.75	0.25	0.061
Yugoslavia	0.67	0.33	0.072

Table 6—POSTULATED AVERAGE MAXIMUM EQUILIBRIUM Sr^{90} BONE LEVELS IN THE WORLD POPULATION
($\mu\mu c$/g Bone Ca)

	Mid-1957		About 1963*		About 2050†	
	Ecol. data	Bone data	Ecol. data	Bone data	Ecol. data	Bone data
United States	3.1	1.7	3.5	1.9	31	17
North temperate latitude	3.2	1.7	3.6	1.9	32	17
South temperate latitude	0.6	0.5	0.7	0.6	6	5
Rest of world	0.8	0.3–0.5	0.9	0.5–0.8	8	3–5
World average‡	(2.8)	(1.5)	(3.1)	(1.7)	(28)	(15)

*Assuming no more weapons tests.
† At equilibrium with a continued test rate of 10 MT equivalents of fission per year.
‡ Population weighted average.

An alternative method of estimating average maximum equilibrium bone levels involves the use of current Sr^{90} bone analyses, by adjusting the data for the pronounced variation in Sr^{90}/Ca ratio in bone as a function of skeletal age. Langham and Anderson[32] estimated the fraction of Sr^{90}/Ca skeletal equilibrium from the rate of skeletal accretion[33] and the rate of increase in integrated fallout shown in Fig. 4. It was assumed that each yearly increment of skeletal growth contains Sr^{90} at a concentration corresponding to the Sr^{90} build-up in the biosphere for that year. For a first approximation, the skeleton was regarded as a unit and the Sr^{90} burden averaged over the entire skeleton.

Calculated values for the apparent fraction of equilibrium Sr^{90}/Ca ratio as a function of age, based on skeletal growth rate alone and a yearly doubling time of the Sr^{90} level are shown by the solid curve of Fig. 5. The points represent Kulp's 1955-1956 data[6] normalized to the 0- to 4-year age group as representing 59 per cent of equilibrium Sr^{90} concentration.

At age 24 (4 years beyond the age at which skeletal growth stops) these data show that 7 to 10 per cent of the skeletal calcium was involved in bone remodeling plus exchange during the period of environmental contamination. If an equivalent fraction of the skeletal calcium of growing subjects is involved in exchange plus remodeling, then the Sr^{90} levels in children would be proportionally higher (dashed line, Fig. 5) than the curve based on skeletal calcium accretion alone. This indeed appears to be the case and indicates that the major factors have been considered in constructing the model. The upper curve in Fig. 5 permits the use of adequate bone data from any age group to predict the average maximum equilibrium Sr^{90} bone level and indicates a value of 0.9 $\mu\mu c$ per gram of Ca by the end of 1955.

Strontium-90 content of skeletons of stillborns[12] during 1955 averaged about 0.5 $\mu\mu c$ per gram of Ca, which gives an average maximum equilibrium level of 1.0 when the placental discrimination factor of 0.5 is considered.[34] Bryant et al.[35] in England reported analyses of 28 bone samples from subjects of all ages collected about January of 1956. Eight samples from persons ranging from 3 months to 3½ years old (average 1⅓ years) averaged 0.9 $\mu\mu c$ of Sr^{90} per gram of Ca, and 11 subjects ranging from 20 to 65 years of age (average 36 years) averaged 0.07 $\mu\mu c$ of Sr^{90} per gram of Ca (after dividing all rib results by 2).[6] The predicted average maximum Sr^{90} equilibrium levels about January 1956, based on these age groups, are 1.0 and 0.9 $\mu\mu c$ per gram of Ca, respectively.

On the assumption that surface deposition levels had a doubling time of one year, an average maximum bone equilibrium level of 1.8 $\mu\mu c$ per gram of Ca was predicted for the north temperate latitudes for the fall of 1956.[32] Data on Sr^{90} fallout from pot collection samples in New York and Pittsburgh[5] show, however, that fallout did not double but increased by only about 50 per cent. On this basis, the predicted level for the north temperate population belt in the fall of 1956 would be 1.4 $\mu\mu c$ per gram of Ca. Kulp[28] applied the same age weighting method to 1956-1957 milk data (assuming a bone-to-diet discrimination ratio of 0.25) and estimated average maximum equilibrium bone levels (by the end of 1956) of 1.1, 0.9, 1.1, and 0.5 for North America, Europe, Asia, and the rest of the world, respectively. A crude estimate of present and future average maximum equilibrium bone levels can be made from the 1956 data

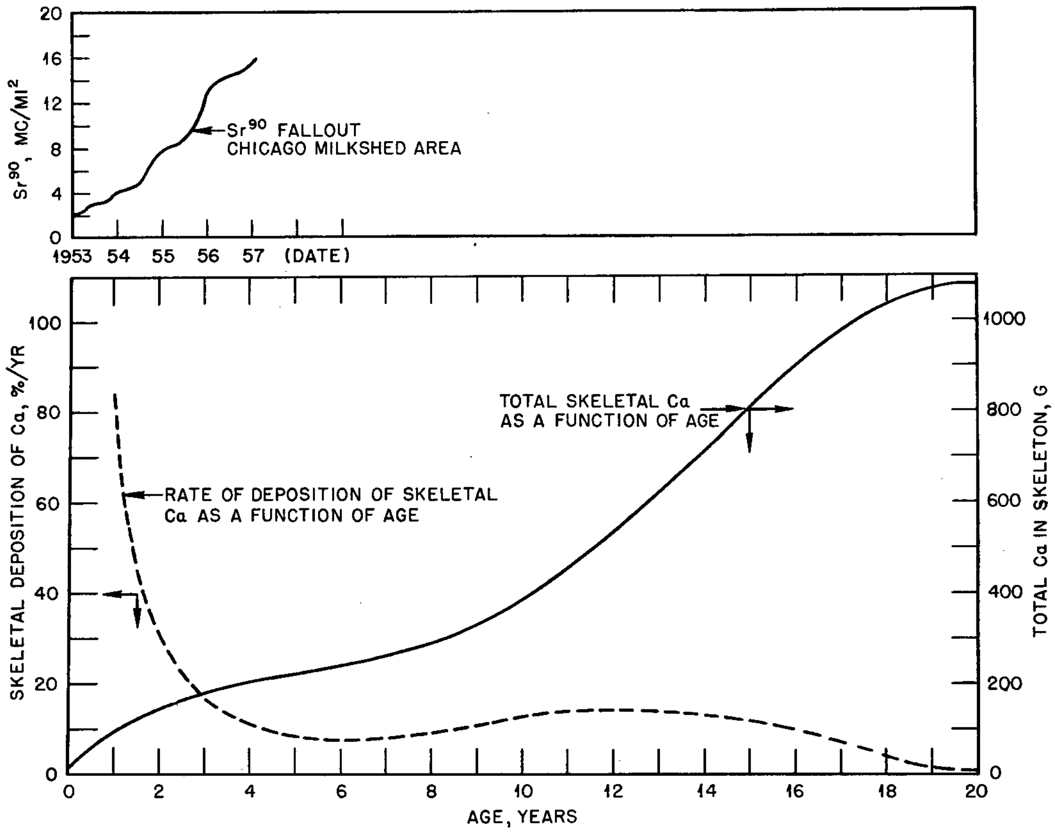

Fig. 4—Rate of skeletal accretion in relation to rate of environmental contamination.

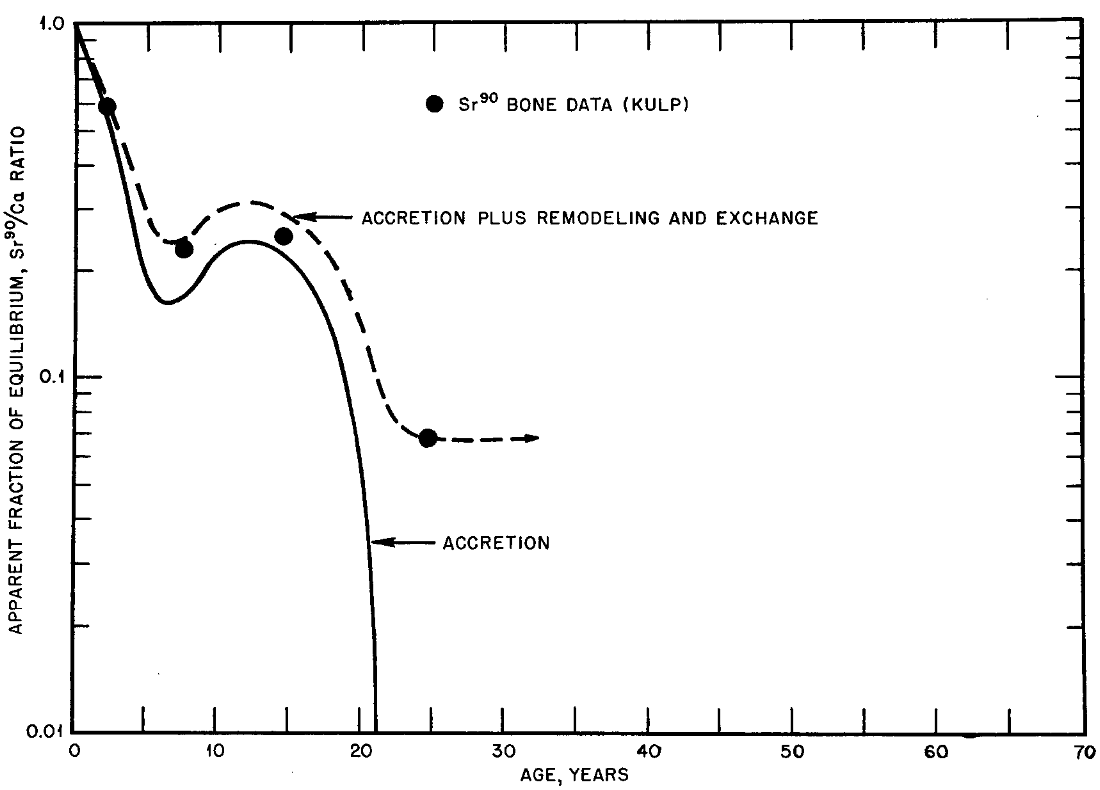

Fig. 5—Apparent fraction of equilibrium Sr^{90}/Ca ratio in relation to skeletal age.

by assuming they will be proportional to the predicted average maximum surface deposition levels given previously. These estimates are compared in Table 6 with those postulated from ecological considerations. Values postulated from ecological discrimination and from bone analyses differ by a factor of about 2. This discrepancy results mostly from the weighted influence of the Far Eastern countries, with low milk consumption and large populations, on the discrimination ratios. Although bone data are probably more reliable than ecological predictions, they may be low since they were predicted on the assumption that the analyses represented the average bone levels for the various regions. Since the number of samples from the United States and Europe exceeded the number from countries with large populations and low relative milk consumption, it is unlikely that they are weighted adequately for population density and dietary habits.

Another troublesome feature of such estimates is that they are average maximum equilibrium levels and make no allowance for such factors as local variations of fallout due to meteorological factors, variations in available soil calcium, dietary patterns and habits, nutritional state of segments of the population, and individual metabolic condition.

Frequency distribution patterns have been reported for stable strontium,[36] natural radium,[37] and Cs^{137} (reference 7) in man. All these nuclides show essentially normal distributions with standard deviations of about 35 per cent. Libby[13] has stated that (at steady state among people living in a given locality) only one person in about 700 will have more than twice the average Sr^{90} burden, and the chances of anyone having as much as three times the average will be about one in 20 million. At present, the Sr^{90} measurements of bone samples from subjects of all ages show a much greater scatter than indicated by a standard deviation of 35 per cent. The greater scatter of the observed values is due largely to the fact that samples came from many localities and (because of the relatively short period of environmental contamination and the age dependence of Sr^{90} deposition) represent varying degrees of equilibrium conditions. The spread may be expected to decrease as equilibrium is approached.[13,28]

Local meteorological conditions will result in increased intensity of fallout in certain localities. The worst possible situation that could come about would be for these "hot spots" to coincide with localities of low available soil calcium in which the population grew up and lived in provincial isolation. Libby[13] has considered this problem in view of the general averaging which occurs in food distribution systems and has postulated that a factor of 5 encompasses the total variation due to all factors.

The question as to the applicability of the normal distribution curve to Sr^{90} equilibrium levels in bone has been raised.[38,39] The observed distribution of stable strontium in bone[36] appears to be log normal rather than normal; in fact the former is rather common for geochemical distribution.[40] The great fundamental difference in the mechanisms of distribution of stable strontium and Sr^{90}, however, greatly weakens agruments based on the analogy. Whether the distribution of equilibrium levels in the bones of the population will be normal or log normal can probably be decided only by more extensive experimental evidence.

4.2 Cesium-137

(a) *Ecological Incorporation and Discrimination.* Cesium is chemically and metabolically similar to potassium, an essential body constituent. If it enters the food chain from the soil (rather than by direct fallout on plants), its uptake via the ecological cycle and incorporation into man should be in relation to the exchangeable or available soil potassium. It is reasonable, therefore, to consider incorporation of Cs^{137} into the biosphere in terms of Cs^{137}/K ratios. Like Sr^{90}, Cs^{137} may be incorporated through direct fallout on vegetation and through soil accumulation and uptake by plants. When Cs^{137} comes in contact with soil, it is rapidly fixed. Leaching studies[41] show essentially all of the Cs^{137} remains in the top inch of soil, even after 200 in. of simulated rainfall. The extent of fixation, as with potassium, is probably proportional to the colloidal content of the soil, being greatest in clays and clay loams and least in light sands and sandy loams.

Plants discriminate heavily against Cs^{137} with respect to potassium, even when the cesium is in an exchangeable form. Auerbach[42] reported uptake of Cs^{137} by corn grown in a lake bed once used for the disposal of reactor wastes. He found that the Cs^{137}/K ratio in the plants was about 1 per cent of the exchangeable Cs^{137}/K ratio in the soil. Menzel[43] obtained a discrimination factor of about 0.04 between Cs^{137}/K in barley and corn and the ratio in available soil potassium, and definitely showed that plant uptake of Cs^{137} was inversely proportional to exchangeable and available soil potassium. Without considering exchangeable soil potassium, others[44,45] have studied the ratio of Cs^{137} per g of dry plant materials to the concentration per g of soil and obtained values of 0.006 to 0.18 (average 0.07). These data suggest that the average Cs^{137} concentration in the potassium of plants should be about 0.04 times the exchangeable Cs^{137} concentration in exchangeable soil potassium.

Exchangeable soil potassium, to a depth of 2.5 in., may vary from about 25 to 400 lbs/acre. About 100 lbs/acre is a reasonable average value for the agricultural soils of the United States. This is equivalent to about 3×10^7 g of exchangeable K/sq mile. Deposition and mixing to a depth of 2.5 in. of 1 mc of Cs^{137} per square mile gives a total concentration of about 30 $\mu\mu c$ per gram of exchangeable soil potassium. Larson et al.[46] added Cs^{137} to three different types of soils and determined the amount that could be extracted with $\underline{N}$ NH_4Ac. The exchangeable Cs^{137} ranged from 13 to 33 per cent with an average of 25. Assuming that 75 per cent of the Cs^{137} is fixed in a form unavailable to plants, the discrimination factor (DF_1) in going from soils-to-plants would be equal to 0.01 and the concentration of Cs^{137} in plant potassium from fallout of 1 mc/sq mile would be about 0.3 $\mu\mu c$/g.

The Cs^{137} deposition level in the northern United States (mid-1957) is estimated at about 46 mc/sq mile, which suggests 15 $\mu\mu c$ Cs^{137} per gram of plant potassium, or a Cs^{137}/K^{40} gamma ratio of 0.18. The calculated ratio is in reasonable agreement with values measured in the Los Alamos large-volume liquid scintillation counter.[7] Measured Cs^{137}/K^{40} ratios in 1957 dried milk samples from the northern United States[47] averaged about 30 $\mu\mu c$/g, giving an estimated discrimination factor (DF_2) of about 2 in favor of Cs^{137} in going from plants-to-milk.

Tracer studies on man[48] show that Cs^{137} and K^{42}, upon ingestion, are absorbed essentially 100 per cent and that they are excreted with mean times of about 150 and 50 days, respectively. These data suggest a discrimination factor of about 3 in favor of Cs^{137} in going from diet (DF_3 and DF_4) to man.* Since 50 per cent of the potassium in a western diet comes from milk and dairy products,[7] the over-all ratio (OR) of Cs^{137}/K is going from soils-to-man equals 0.5 $(0.01 \times 2 \times 3) + 0.5\ (0.01 \times 3)$, or 0.045. In other words, the Cs^{137} concentration per gram of body potassium should be about 4.5 per cent of the total Cs^{137} concentration per gram of exchangeable soil potassium.

Anderson et al.[7] suggested that Cs^{137} may be entering the biosphere and man largely through direct fallout on vegetation and not by plant uptake from the soil. This suggestion was based on the following considerations: (1) The high fixation of Cs^{137} in soil and its very slow leaching rate make it unlikely that the Cs^{137} can be in equilibrium with exchangeable soil potassium to the depth of the plant feeding zone. (2) The Cs^{137}/K^{40} ratio of people does not seem to be increasing in relation to integrated Cs^{137} fallout. (3) Cs^{137}/K^{40} ratios in milk show sharp increases during periods of weapons testing, after which they rapidly return to near their previous levels, suggesting the possibility of a quasi-equilibrium condition with the rate of stratospheric fallout. The relatively small effect of a sharp increase in the Cs^{137} content of foods during periods of tropospheric fallout on the Cs^{137} content of people can be explained by the simple model shown in Fig. 6 (reference 7). A step function change in the foodstuff level will be followed by a $(1 - e^{-\lambda t})$ change in the population level (where λ is the biological elimination rate), and a new equilibrium value will be reached only after an elapsed time of about one year. If the foodstuffs return to their previous value before equilibrium is attained, the population level will cease rising and will return to its previous value with a half-time corresponding to the biological elimination rate.

(b) *Cs^{137} Levels in the Population.* Concentrations of Cs^{137} per gram of body potassium can be estimated from predicted average maximum surface deposition levels given in Tables 2, 3, and 4 and the ecological considerations discussed previously. One millicurie of Cs^{137} per square mile gives a specific activity of 30 $\mu\mu c$ per gram of exchangeable soil potassium. The specific activity times the surface deposition levels times the over-all discrimination ratio (0.045) gives the specific activity per gram of body potassium for the population of any fallout area, assuming no equalization between areas through food distribution channels.

*A value of 3 for the discrimination factor from milk-to-man (DF_3) is not confirmed by measurements on people and milk from the same areas.[47] These data strongly suggest a discrimination factor of approximately one.

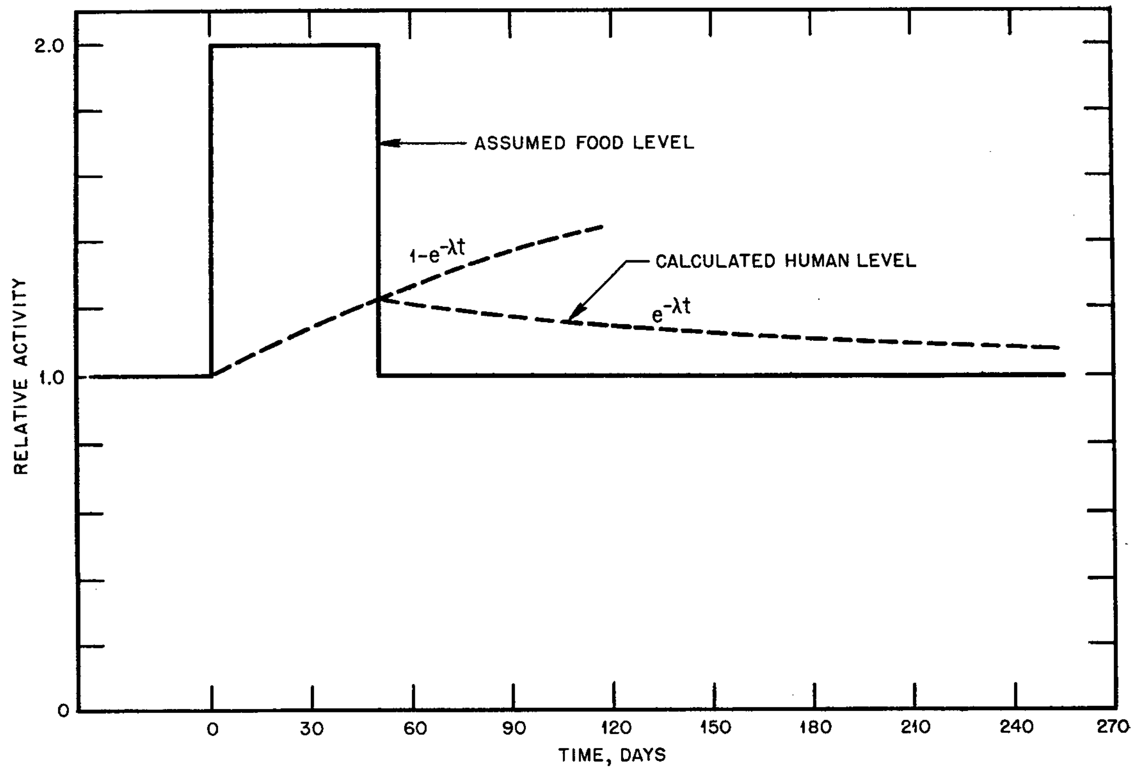

Fig. 6—Calculated effect of temporary increase in Cs^{137} level of the diet on the Cs^{137} level in people.

Table 7—ESTIMATED PRESENT AND FUTURE CONCENTRATIONS OF Cs^{137} IN THE POPULATION ON THE BASIS OF ECOLOGICAL CONSIDERATIONS

	Cs^{137} concentration		
Region	Mid-1957, $\mu\mu c$/g of K	1965—No more tests, $\mu\mu c$/g of K	Continued tests,* $\mu\mu c$/g of K
Northern United States	62	69	620
North temperate latitudes	34	37	340
South temperate latitudes	10	11	100
Rest of world	7	8	70
World average†	(32)	(36)	(320)

* Assuming equilibrium with continued testing at the past 5-year rate (equivalent to 10 megatons of fission per year).

† Population weighted average on the basis of present world population distribution.

Present and future levels of Cs^{137} in the population of various regions, estimated from ecological considerations, are shown in Table 7.

Measurements of Cs^{137}/K^{40} gamma ratios of the United States population during 1956 averaged about 0.5 (reference 7), which corresponds to 41 $\mu\mu c$ Cs^{137} per gram of body potassium or about 0.0055 μc of Cs^{137} in the total body assuming 133 g of potassium in a 70-kg man. Measurements during 1957 (reference 47) gave average Cs^{137} concentrations of 45 and 50 $\mu\mu c/g$ of body potassium for the general United States population and the population of the northern states, respectively. Levels in the United States population might be expected to show little variation because of the equalizing effect of general food distribution systems.

The value of 62 $\mu\mu c$ per gram of K for the population of the northern United States, estimated from ecological considerations, agrees very well with the average value of 50 $\mu\mu c$ per gram of K derived from measured Cs^{137}/K^{40} ratios. The agreement may be purely coincidental and could result from direct fallout on vegetation, fortuitously making up for non-equilibrium of Cs^{137} with exchangeable soil potassium.

The estimates of future levels given in Table 7 are predicated on the assumption that Cs^{137} is entering the biosphere largely through the soil and that the contribution of direct fallout on vegetation is negligible. In this case, Cs^{137} levels in people might be expected to rise somewhat in accordance with the estimated values. If present levels represent a quasi-equilibrium with direct fallout, population levels (with cessation of testing) might be expected to start dropping immediately with a half-time comparable to the half-time of stratospheric fallout. In this case, continued testing at the past 5-year rate will produce little or no increase in the average Cs^{137} of the population. Present levels in the biosphere actually may be a result of significant contribution from both direct fallout and ecological integration, in which case the truth will be somewhere in between. It should be possible to decide among these alternatives within the next few years.

4.3 Plutonium-239

Ecological Incorporation and Discrimination. Although the presence of naturally occurring Pu^{239} in pitchblende concentrate has been reported,[49] its existence in the biosphere can be attributed entirely to the detonation of nuclear weapons. Unlike Sr^{90} and Cs^{137}, it is chemically unrelated to any essential constituent of plants or animals.

When plutonium is deposited in soil it is extremely tightly bound, and the establishment of uniform distribution to the depth of the plant feeding zone may require years. A plutonium deposition level of 1 mc/sq mile would be equivalent to about 5×10^{-3} $\mu\mu c$ per gram of soil when uniformly mixed to a depth of 2.5 in. Absorption of plutonium by barley from a sandy soil was studied by Rediske,[44] who found that the ratio of plutonium concentration in dry plant material to the concentration in the soil was 9×10^{-4}. When ingested by man and domestic animals, absorption of plutonium is only about 0.01 per cent. Once it is absorbed, about 85 per cent is fixed in the skeleton and largely retained throughout the life-time of the animal. The apparent half-time of plutonium elimination by man is about 200 years, which means it is essentially completely cumulative on absorption. Its high fixation in the skeleton of domestic animals, however, provides an additional discrimination factor of about 10^{-2} in meat and dairy products. The over-all discrimination ratio in going through the ecological cycle from soils to man is at most 5×10^{-8}. The estimated present average maximum plutonium deposition level for the north temperate population belt would lead to a plutonium uptake of the order of 10^{-7} of the recommended maximum permissible level from the consumption of a 3000-calorie diet for 70 years. With such a large discrimination, it is quite unlikely that incorporation of plutonium fallout into man via the ecological chain can be of any consequence. Incorporation via inhalation and direct fallout on vegetation, although insignificant also, probably would be much greater than incorporation via ecological transport.

4.4 Iodine-131

Radioactive iodine from weapons tests has been reported in human thyroids[50,51] and in the thyroids of domestic animals.[50–54] Because of its 8-day half life, I^{131} cannot integrate in the biosphere and its concentration in thyroids fluctuates in relation to tropospheric fallout during periods of nuclear testing. Van Middlesworth[50] reported the analysis of 175 human and 1044 cattle thyroids collected from the Memphis, Tenn., area during November 1954 to March 1956, and Comar et al.[51] reported analysis of 1165 human and 853 cattle thyroids collected from several countries during the period from January 1955 to December 1956. These data show that the concentration of I^{131} in cattle thyroids is about 18 to 200 times that of man. The average concentration in cattle thyroids during the period from November 1954 to December 1956 appears to be about 0.5 (reference 54) and the average peak level in man about 0.005 mμc/g.[51]

The principal mode of entry of I^{131} into domestic animals seems to be through ingestion of direct fallout on forage. Grazing animals show a much higher thyroid uptake than do lot fed. The mode of entry of I^{131} into man is believed to be via direct inhalation with ingestion of contaminated milk as a secondary route. Following oral feeding to cattle, about 6 per cent of the ingested I^{131} appears in the first week's milk production.[55] The average milk concentration during the 1955 period of high level fallout was estimated at about 0.2 mμc/liter, which is a factor of 500 below the value chosen as unsafe for public consumption during the recent United Kingdom Windscale reactor accident.[56]

Since I^{131} does not accumulate in the biosphere, the above values may be considered crude average maximum equilibrium levels with the present rate of testing. Although large local fluctuations may be expected from time to time as a result of tropospheric meteorological variations and proximity to test sites, the average I^{131} content of the thyroids of man and livestock should not increase materially with continued testing at the past 5-year rate.

One mμc of I^{131} per g of thyroid delivers a radiation dose of about 10 mrad/day.[53] The average I^{131} concentrations during the 1955 peak period of fallout delivered about 35 and 0.3 mrad/week to livestock and man, respectively. The integrated dose received during 1955 was actually much lower.[51]

If the 1955 peak levels are maintained in people and livestock, the yearly integrated dose to the thyroid will be about 15 and 1500 mrad/year, respectively. For man, this is about one per cent of the recommended maximum permissible level for continuous exposure of large segments of the population.

The external radiation dose to the neck area in infants and children that possibly has caused later thyroid malignancy is estimated at 200 to 750 r (reference 57), and about 900 rad to the thyroids of sheep chronically fed I^{131} over a 6-year period failed to produce any observable damage.[58]

In the event of nuclear war, it is conceivable that I^{131} could constitute a significant acute danger in localized areas. However, there seems to be very little probability that I^{131} levels introduced into the biosphere by continuation of weapons tests at the past rate will pose any general hazard to man and domestic animals.

5 SIGNIFICANCE OF Sr^{90} AND Cs^{137} LEVELS IN THE POPULATION

5.1 Strontium-90

The potential significance of present and predicted Sr^{90} levels in bone can be evaluated only in relation to human experience, which is indeed inadequate. Bone sarcoma has resulted from a fixed skeletal burden of 3.6 μc of pure Ra^{226}, and nondeleterious bone changes have been observed in persons having only 0.4 μc for a period of 25 years.[59] Necrosis and tumors of the bone have occurred also several years after large doses of X rays,[60] and consideration of human experience with leukemogenic effects of X and gamma radiation[61–63] suggests that about 80 rads may double the incidence of leukemia.

The only other human experience with which present and predicted levels of Sr^{90} may be compared is that arising from natural background radiation. Natural background dose to the bone (during a 70-year lifetime) may vary from about 8 to 38 rem.[64] The major contribution to background variation is differences in the radium levels of soils and minerals. The average natural skeletal radiation dose rate was carefully evaluated by Dudley and Evans[65] and their data are shown in Table 8.

Figure 7 shows a general summary of estimated skeletal radiation doses from accepted maximum permissible levels and from present and predicted Sr^{90} burdens in relation to human experience. The maximum permissible level of Sr^{90} (100 μμc per gram of Ca) is estimated to

Table 8—AVERAGE NATURAL BACKGROUND RADIATION TO THE SKELETON[65]

Source of radiation	Skeletal dose rate, mrem/year	Total dose, to age 70 rem
K^{40} (internal)	8	0.56
Ra^{226} (internal)	12	0.84
MsTh (internal)	12	0.84
RaD (internal)	12	0.84
Cosmic rays (external)	30	2.10
Local gamma rays (external)	60	4.20
Total	134	9.40

deliver about 8.5 rads* to the skeleton during a 70-year lifetime. This is comparable to the average natural background dose to the bone for the same time period and a factor of about 4 below the maximum natural background dose to which small segments of the general population may be exposed as a result of differences in altitude and natural radium content of soils and minerals. It is a factor of 40 below the lowest skeletal dose which has produced minimal

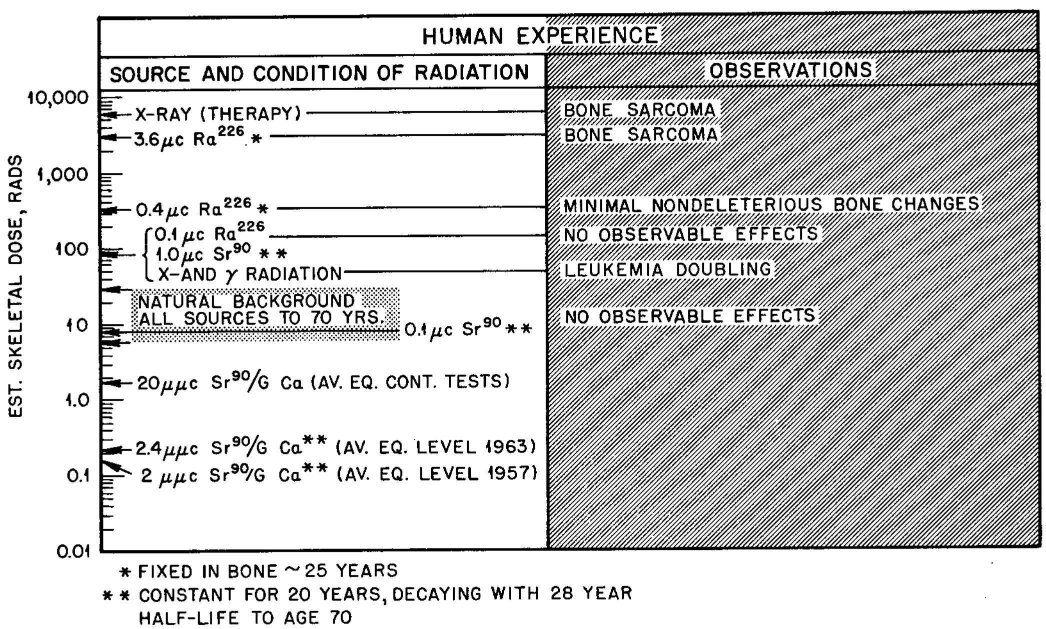

Fig. 7—Estimated Sr^{90} skeletal radiation dose in relation to human experience.

nondeleterious bone changes and a factor of about 10 below the leukemia doubling dose. These data suggest that the present average maximum Sr^{90} equilibrium level will result in a lifetime radiation dose of 1 to 2 per cent of the accepted maximum permissible level for the general population. With continued biospheric contamination indefinitely at the past 5-year rate, the average maximum radiation dose may approach about 20 per cent of the presently accepted maximum permissible level.

*Eight and five-tenths rads is the calculated dose assuming incorporation to age 20 and decay to age 70 with no more incorporation. If equilibrium were maintained, the calculated skeletal dose would be about 21 rads. Since some but not all of the skeleton undergoes remodeling plus exchange, somewhere between 8 and 21 rads is probably more correct.

Threshold versus Nonthreshold Response. If chronic effects of radiation are threshold phenomena, 100 $\mu\mu c$ of Sr^{90} per gram of Ca must be looked upon as a true maximum permissible level and not as an average for large segments of the population. If chronic effects are nonthreshold phenomena and linear with dose (Fig. 8), the maximum permissible level of Sr^{90} in the bones may be expressed in terms of a population or group average, and a portion of the natural population incidence of the effect in question must be attributed to natural background radiation. In this case, the potential hazard should be established on the basis of probability of risk averaged over the entire population or group.

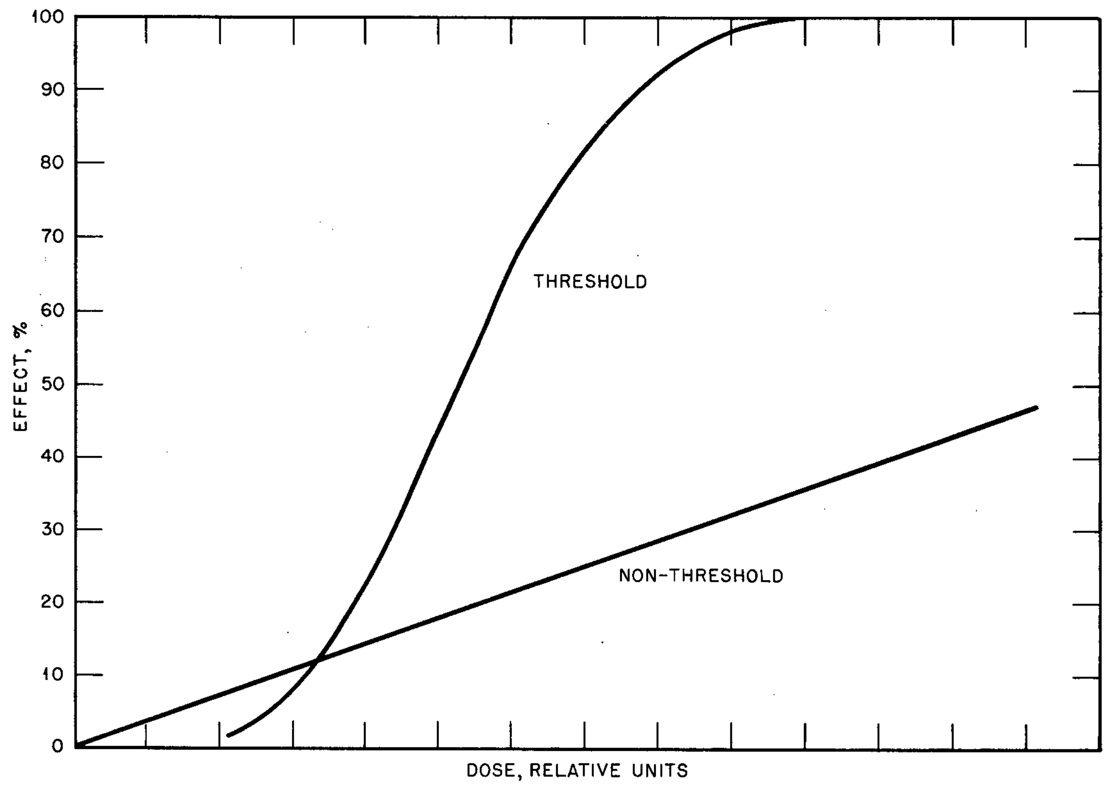

Fig. 8—Threshold and nonthreshold response as a function of radiation dose.

At present it is impossible to say whether leukemogenic and sarcogenic responses to chronic radiation dosage are threshold or nonthreshold relationships. The recent Congressional Hearings[1] failed to produce any degree of unanimity of opinion among the experts. Argument for a linear relationship between incidence of leukemia and radiation dose was presented recently by Lewis.[62] His argument was based on all major sources of human data and included a consideration of the Japanese atomic bomb survivors, the British cases of X-ray treated spondylitis, X-ray treated cases of thymic enlargement, practicing radiologists, and spontaneous incidence of leukemia in Brooklyn, New York. The validity of his conclusion was questioned by Warren, Brues, and others during the Congressional Hearings.[1] Radiation as a carcinogenic agent has been discussed at length by Brues,[66] who stated that the relation between radiation dose and carcinogenic effect is not easy to find and a critical experiment has yet to be done which will clearly indicate, even in a single instance, what the relation is over more than a small range of dosages. While admitting that it is not known, he proposes that a threshold relationship between radiation dose and tumor incidence does exist.[67]

Without adequate scientific basis but for the purpose of presenting the worst possible potential hazard from Sr^{90} biospheric contamination, a comparison may be made between the radiation dose from present Sr^{90} bone levels and the postulated leukemia doubling dose.[62] Assuming a nonthreshold response and that 10 per cent of the natural incidence of leukemia in the population (6/100,000) is a result of natural background radiation, the average maximum Sr^{90} equilibrium bone level for the north temperate population belt would be equivalent to about

1.2 leukemia cases per 10 million population. Averaged over the world population of 2.6 billion, this would produce an increased leukemia burden of 300 cases per year. A world average of 100 $\mu\mu c$ of Sr^{90} per gram of Ca would be equivalent to about 16,000 cases.

The above analogy assumes that Sr^{90} beta radiation induces leukemia of bone marrow origin at the same rate (per unit of absorbed dose) as X and gamma rays. Much of the beta radiation from Sr^{90} will be absorbed in the bone and not reach the hematopoietic tissues at all. Experiments by Brues et al.[68] suggest that Sr^{89} (half-life 55 days, E_β = 1.5 Mev) administered to mice is relatively more spectacular as an osteosarcogenic agent than a leukemogenic agent. Furthermore, leukemia was not a significant finding in the radium dial painters[69,70] or in the radium-injection cases.[59]

Bone sarcoma is more apt to result from Sr^{90} than is leukemia. Human data on radiation-induced osteogenic sarcoma are not adequate to provide even the crudest estimate of the dose response relationship, the population doubling dose, or the fraction of normal population incidence (about 2/100,000) attributable to natural background.

Under the same conditions, the potential risk to the population from bone sarcoma, however, would be less than that calculated for leukemia, since its natural incidence in the population is lower than that of leukemia.

Table 9—CONCENTRATION OF Cs^{137} IN THE GONADS OF RATS

Days after administration	Concentration gonads/muscle*
Testes	
2	0.70
5	0.71
10	0.52
Ovaries	
2	0.82

*Average of three animals per point.

5.2 Cesium-137

The present average Cs^{137} level in the population of the United States is about 45 $\mu\mu c/g$ body potassium. This is equivalent to 0.006 μc per person. Cs^{137}, like potassium, is concentrated in muscle and the radiation dose it delivers is essentially whole-body. The dose delivered is equivalent to approximately 1 mr/year. Taking into consideration the respective energies of their radiations, the dose from the present level of Cs^{137} is about one-twentieth of that from natural K^{40}, or about one per cent of the average natural background. If Cs^{137} is entering man largely through the ecological cycle, continued testing at the past 5-year rate may result in an average radiation dose to the United States population of about 10 mr/year, or about 10 per cent of natural background, and a weighted world population average of about 7 per cent of background. Because of nonhomogeneities in fallout and uptake, a few persons may receive doses about 5 times the average. If Cs^{137} is entering man largely through direct fallout on vegetation and not through ecological integration, continued testing may not increase the average Cs^{137} dose significantly above the present levels.

Concern has been expressed[71] over the possible genetic implications of selective concentrations of Cs^{137} in the gonads. The data in Table 9 show the ratio of Cs^{137} concentration in the gonads of rats to that in muscle. The testes and ovaries concentrate Cs^{137} to the extent of about 70 and 80 per cent of muscle, respectively, and the elimination time from the testes appears shorter. Therefore, the radiation dose delivered to the gonads is comparable to that delivered to muscle, or about 2 mr/year at present United States average Cs^{137} levels.

6 DISCUSSION AND SUMMARY

Past testing of nuclear weapons has produced between 5 and 6 megacuries of Sr^{90} (equivalent to 50 to 60 megatons of fission energy). About 90 per cent of the production has occurred since 1952 from testing of weapons in the megaton class. United States Pacific tests have been held under conditions that maximized local fallout (where Sr^{90} is of no concern because of the vast calcium reservoir of the ocean) and minimized world-wide contamination. Soil data suggest that about 1.6 megacuries of Sr^{90} have been distributed as long-range fallout. The present stratospheric reservoir is estimated at about 2.4 megacuries by Libby,[12] and at 1.1 ± 0.93 in this report. Present integrated surface deposition levels are such that the rate of Sr^{90} decay on the ground is almost equal to the rate of stratospheric fallout. If weapons tests were to stop, integrated surface deposition levels in the north temperate latitudes would probably increase by no more than 10 per cent, reaching a maximum in about 1963-1970.

Unfortunately, because of the locations of the United States and USSR test sites and tropospheric and stratospheric meteorological phenomena, long-range fallout is maximized in the north temperate latitudes where over 80 per cent of the world's population lives. The present average soil level in the northern United States is about 35 mc/sq mile, and the average level elsewhere in the same general latitudes may be about 20 mc/sq mile. Deposition levels elsewhere in the world are not potentially important with regard to general world health because of population distribution.

Estimates of average maximum Sr^{90} equilibrium bone levels for the northern United States and the north temperate population belt (from weapons tests to date) vary from about 1 to 4 $\mu\mu c$ per gram of Ca. Controversy over the issue of stopping or continuing bomb tests has resulted in greater apparent public confusion over the potential hazard of world-wide Sr^{90} fallout than seems justified by the factor of 4 differences in estimates of average maximum equilibrium bone levels. This confusion has resulted largely from differences in choice of reference as to average maximum permissible Sr^{90} levels applicable to the general population and differences in opinion as to an appropriate factor of allowance for nonhomogeneity of fallout and bone uptake.

Libby[5,12] and Kulp,[72] before any authoritative statements regarding a Sr^{90} MPL for the general population had been issued, used the occupational MPL (1000 $\mu\mu c$ per gram of Ca) as a reference. Later the National and International Commissions for Radiological Protection recommended that the MPL for large segments of the general population should be one-tenth (100 $\mu\mu c$ per gram of Ca) that for occupational exposure. The U. S. National Academy of Sciences-National Research Council report[73] inferred that 50 $\mu\mu c$ per gram of Ca might be considered as a safe level for the general population. The British Medical Research Council report,[61] while acknowledging that the maximum allowable concentration of Sr^{90} in the bones of the general population should not be greater than 100 $\mu\mu c$ per gram of Ca, stated that immediate consideration should be required if the concentration in human bones showed signs of rising greatly beyond one-hundredth (10 $\mu\mu c$ per gram of Ca) of that corresponding to the maximum permissible occupational level. Lapp[74] has stated also that the MPL for the general population perhaps should be one-hundredth of the occupational value. All of these numbers have been brought to public attention during the controversy over continued weapons tests.[1]

Confusion has been increased also by the use of various safety factors for nonhomogeneity of fallout and bone uptake. Articles have appeared in which no factor was used,[5,6,12] and others have appeared in which factors of 5[13] and 10[74,75] were recommended.

The effect of choice of values for the acceptable general population MPL and the choice of safety factors for nonhomogeneity of distribution and uptake are shown by the date in Table 10. These data were derived by simple proportionality (Maximum Bone Level from Present Tests: 50 megatons :: Acceptable MPL: X) and show the megatons of fission energy release (over a short period) required to bring the average maximum equilibrium bone levels of the population to the various permissible values that have been called to public attention. The table also indicates the effect of various nonhomogeneity factors on the world average population level. These data show a variation of a factor of about 1000 in the megaton equivalents of fission that could be detonated, depending on whether one wishes to be ultraconservative and use the highest safety factor for nonuniformity and the lowest value recommended for the general population, or be the opposite and use the occupational MPL and no safety factor for nonuniformity. The most important point to the data is that they explain the principal reasons for public confusion and show that the major areas of uncertainty are: (1) the maximum permissible level for Sr^{90} as applied to the general population; and (2) the deviation of equilibrium bone values from the mean.

Table 10—ALLOWABLE MEGATONS OF FISSION ENERGY RELEASE AS A FUNCTION OF VARIOUS GENERAL POPULATION MPL's

Source of equilibrium bone level estimate and region	Av. max. bone level (no more testing) $\mu\mu c/g$ of Ca	Allowable MT of Fission yield			
		10 $\mu\mu c/g$ of Ca	50 $\mu\mu c/g$ of Ca	100 $\mu\mu c/g$ of Ca	1000 $\mu\mu c/g$ of Ca
United States					
Libby (13)-Ecological data	3.9–1.7	130–300	650–1500	1300–3000	13,000–30,000
Kulp (6)-Ecological data	2	250	1250	2500	25,000
Kulp (28)-Bone data	1.5	300	1500	3000	30,000
Eisenbud (76)-Milk data	4	120	600	1200	12,000
This paper-Ecological data	3.5	140	700	1400	14,000
This paper-Bone data	1.9	250	1250	2500	25,000
North Temperate Latitudes					
This report-Ecological data	3.6	140	700	1400	14,000
This report-Bone data	1.9	250	1250	2500	25,000
World Average					
Kulp (6)-Ecological data	1.3	380	1900	3800	38,000
This report-Ecological data	3.1	160	800	1600	16,000
This report-Bone data	1.7	150	1500	3000	30,000
World Average (no factor for distribution)	2	250	1250	2500	25,000
Average × 1/5 (for nonuniformity)		50	250	500	5,000
Average × 1/10 (for nonuniformity)		25	125	250	2,500

The most important question regarding the potential hazard of long-range Sr^{90} fallout is in relation to future weapons testing. If there is an upper limit to the amount of Sr^{90} in the bones of the population that can be safely tolerated, then the megaton equivalents of fission products that can be contributed per year to the biosphere by all nations is limited.

If Sr^{90} contamination from weapons testing by all nations continues at the same rate as has occurred during the past 5 years, equilibrium will be reached in about 100 years. At equilibrium the amount of Sr^{90} which will disappear each year from the environment, due to radioactive decay, will equal the amount that is being produced, and continuing weapons tests will not result in any further increase in the population bone levels.

Libby[13,17] and others[18] have predicted that soil and bone levels at equilibrium with the present test rate will be 8 to 13 times the present values. On the basis of present average maximum equilibrium Sr^{90} bone levels postulated from the considerations set forth in this paper, the bones of the United States population will reach a steady state with the present testing rate at a value of 17 to 31 $\mu\mu c$ per gram of Ca. The equilibrium value for the weighted average world population will be 15 to 28 $\mu\mu c$ per gram of Ca.

Libby[13] has stated that something between 5 and 20 $\mu\mu c$ per gram of Ca would be the average maximum Sr^{90} concentration in the bones of the United States population if testing continued indefinitely at the average rate of the past 5 years. Kulp[28] predicted an equilibrium level will be approached in the North American population of about 8 $\mu\mu c$ per gram of Ca in about 50 years, and Neuman[18] in testimony before the Congressional Subcommittee suggested equilibrium bone levels of about 90 $\mu\mu c$ per gram of Ca may be reached in the northern United States. The values given above show disagreement by a factor of about 10. If, however, we accept as a reasonable average the values developed in this paper, the average Sr^{90} radiation dose to the bones of the population of the northern United States, at equilibrium with continued testing at the past rate, may be about 20 to 30 per cent of the average radiation dose from natural background, or about 20 to 30 per cent of the maximum permissible level adopted by the National and International Commissions. Since individual variations may result in a small number of people accumulating Sr^{90} burdens that are 5 times the average, the radiation dose to these few individuals may approach as an upper limit 100 to 150 per cent of the recommended maximum level. If testing is continued at the present rate for 30 years, the average level of Sr^{90} in the population of the northern United States may be about 10 to 15 per cent of natural background. This may result in a few people approaching body burdens about 50 to 75 per cent of the recommended maximum. Strontium-90 burdens in the weighted world average population will be essentially the same.

The average Cs^{137} levels presently in the population of the United States is about 45 $\mu\mu c$ per gram of K. This amount of Cs^{137} is delivering a radiation dose of about 1 mr/year, or about 1 per cent of the natural background dose. The present population weighted world average may be about 32 $\mu\mu c/g$. Continued testing at the past 5-year rate until equilibrium may result in an average world population Cs^{137} radiation dose of about 7 per cent of background, depending on whether Cs^{137} is entering the biosphere largely via ecological transmission from the soil or by direct fallout on vegetation. In either case, Cs^{137} appears to be relatively less important than Sr^{90} as a potential internal hazard from world-wide fallout. Other long-lived radionuclides, including Pu^{239}, appear to be orders of magnitude less significant than Sr^{90} and Cs^{137}.

These considerations suggest that the past rate of weapons testing, if continued for several years, will not produce internal radiation levels that will exceed the general population maximum permissible levels recommended by the National[77] and International[21] Commissions on Radiological Protection. Although this leads to the conclusion that the present rate of biospheric contamination poses no serious potential somatic hazard to world health, the great uncertainties involved make it imperative that the problem be kept under constant scrutiny if weapons tests are to continue. Fortunately, present levels are not critical and the slow rate of biospheric build-up affords time for continued intensive and extensive study.

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DISCUSSION OF METEROLOGICAL FACTORS AND FALLOUT DISTRIBUTION*

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1 INTRODUCTION

It is typical of nuclear tests that the radioactivity of the fission products has been released to the atmosphere. The deposition of these fission products on the earth's surface is loosely termed "fallout." The total quantity of fallout depends primarily on the total fission yield of the nuclear device, but the area in which the deposition occurs depends on a number of features, such as the atmospheric winds, the yield of the bomb, the terrain, and altitude of the explosion. It is the purpose of this discussion to review the atmospheric processes that transport the radioactive debris back to the ground.

Fallout is assigned to three classes:[1] first, local or close-in, which is deposited within the first 24 hr after the detonation; second, intermediate or tropospheric, which is deposited largely within the first 30 to 60 days; and finally, delayed or stratospheric, which can take many years to be deposited.

2 LOCAL FALLOUT

The main feature that distinguishes local fallout from other categories is its appreciable settling speed. The particles are large and heavy enough to fall through the air. As the particles settle, they are transported by the winds. Particles originating at different altitudes are acted upon by differing winds, causing fallout in different areas. If the winds blow in approximatply the same direction at all altitudes, as frequently occurs, the pattern is long and narrow. This gives rise to the familiar cigar-shaped pattern, with the larger particles, or those originating at lower levels, falling closer to the burst point. If, on the other hand, there is appreciable change of the wind direction with altitude, then the patterns may be very broad and may show no similarity to a cigar.[2] If the winds are extremely light, the particles will settle back to earth close to ground zero and will make for very intense nearby radioactive areas. If the speeds are comparatively strong, the same particles will be carried to greater distances and will become diluted by being spread over larger areas with lower radiation intensities. Further, from day to day one finds that the wind direction changes, varying the general direction of the fallout area.

The meteorological principles governing the prediction of local fallout are well known.[2] Although there is considerable uncertainty in the prediction of the winds, this is not the only uncertainty in predicting dosages on the ground. One must also associate a known amount of radioactivity with each particle size at every altitude in the nuclear cloud. It is impossible to obtain this radiological data from first principles based on the thermodynamics of the fireball and the chemical and physical properties of the entrained debris. Instead, one uses observed

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deposition patterns to reconstruct the initial radioactivity of the particles in the nuclear cloud by using winds to assign a point on the ground to a given particle size and altitude of origin. There is a considerable body of local fallout information for the relatively low-yield explosions that occur in the Nevada Test Site, and predicting dosages in the unpopulated areas adjacent to the Nevada Test Site is reasonably competent. There is appreciably less fallout information for high-yield explosions in the Pacific, and one cannot be sure that the particle size distribution will be similar for bombs exploded over large cities as for the Pacific coral or the Nevada desert.

On the positive side the meteorologist can provide certain information about local fallout. First, he can tell the area in which there may be some radioactivity based on the winds and crude knowledge of the explosion characteristics. Second, he can tell the approximate time of arrival of local fallout; therefore, for civil defense applications, warning to the down-wind population is possible.

The Federal Civil Defense Administration (FCDA) has prepared a hypothetical bombing attack on the U. S., using some 2500 Mt of fallout in the form of 250 bomb drops. The picture for FCDA Operation Sentinel, which was shown publicly for the first time at the congressional hearings on fallout,[2] illustrates the fallout pattern as it would appear 24 hr after this widespread bombing, using Nov. 20, 1956, winds (Fig. 1). The code in the lower left-hand corner of the figure indicates the dosages in the fallout pattern. It is quite evident that there is very little area east of the Mississippi Valley free of fallout. Secondly, I should like to make it clear that some of the uncontaminated areas in the western part of the country would be covered with fallout if another set of winds or ground zeros were used.

The main purpose for including Fig. 1 is to put any remarks on test fallout in perspective. Nuclear tests provide milliroentgens of radioactivity in populated regions[3] in comparison with tens, hundreds, or thousands of roentgens to be found during a nuclear war.

3 INTERMEDIATE FALLOUT

Fallout particles come in a continuous spectrum of sizes. It is believed that fallout that occurs more than a few days after an explosion consists of particles with negligible settling speeds. Probably the bulk of the fallout that occurs during the period from 1 to about 60 days originates in the troposphere, even for explosions whose clouds go into the stratosphere. The justification for saying that most of the intermediate fallout is deposited within 30 to 60 days is shown in Fig. 2. The ordinate shows the amount of radioactivity measured by air filtration in the lower atmosphere on a logarithmic scale plotted against time in weeks. The concentration decreases rapidly in time with a half time of about 20 days for Nevada tests whose nuclear clouds do not enter the stratosphere. It can be seen that the delayed fallout from the megaton or thermonuclear tests do not show this rapid decrease with time.

It has been known for many years that the prevailing winds blow west to east or in few instances, east to west. Thus, transport in a north-south direction is much slower than in a west-east direction. This results in a fallout band,[4] which lies almost entirely near the latitude of the source. Figure 3 shows this for a Nevada test series in the spring of 1953. Intermediate or tropospheric fallout from tests conducted in the Pacific Proving Grounds is similarly distributed in a band around latitude 11°N.

The technique for sampling fallout by using gummed film collectors is quite uncertain, but, if it is accepted as correct, then 25 per cent of all the fission products in a test appears as intermediate fallout for Nevada tests.[1] The fraction of the fission products deposited in intermediate fallout from Pacific tests is even less well known because of the vast unsampled ocean areas in the tropics, but the fraction is considerably smaller than 25 per cent.[1]

In terms of evaluating hazard from intermediate fallout, two points should be noted: first, although all the nonlocal fallout fission products formed in kiloton-sized explosions contribute to intermediate fallout, the amount produced by such an explosion is very small compared to that of a high-yield explosion. Thus, 500 nominal (20 kt) bombs provide the same amount of fission products, roughly speaking, as one 10-Mt fission bomb. On the other hand, the deposition per unit area is clearly higher in those regions in which tropospheric fallout occurs than would be the case if the radioactivity were distributed uniformly over the entire globe. Thus, the average concentration at latitude 40°N in Fig. 3 is about five times higher than would

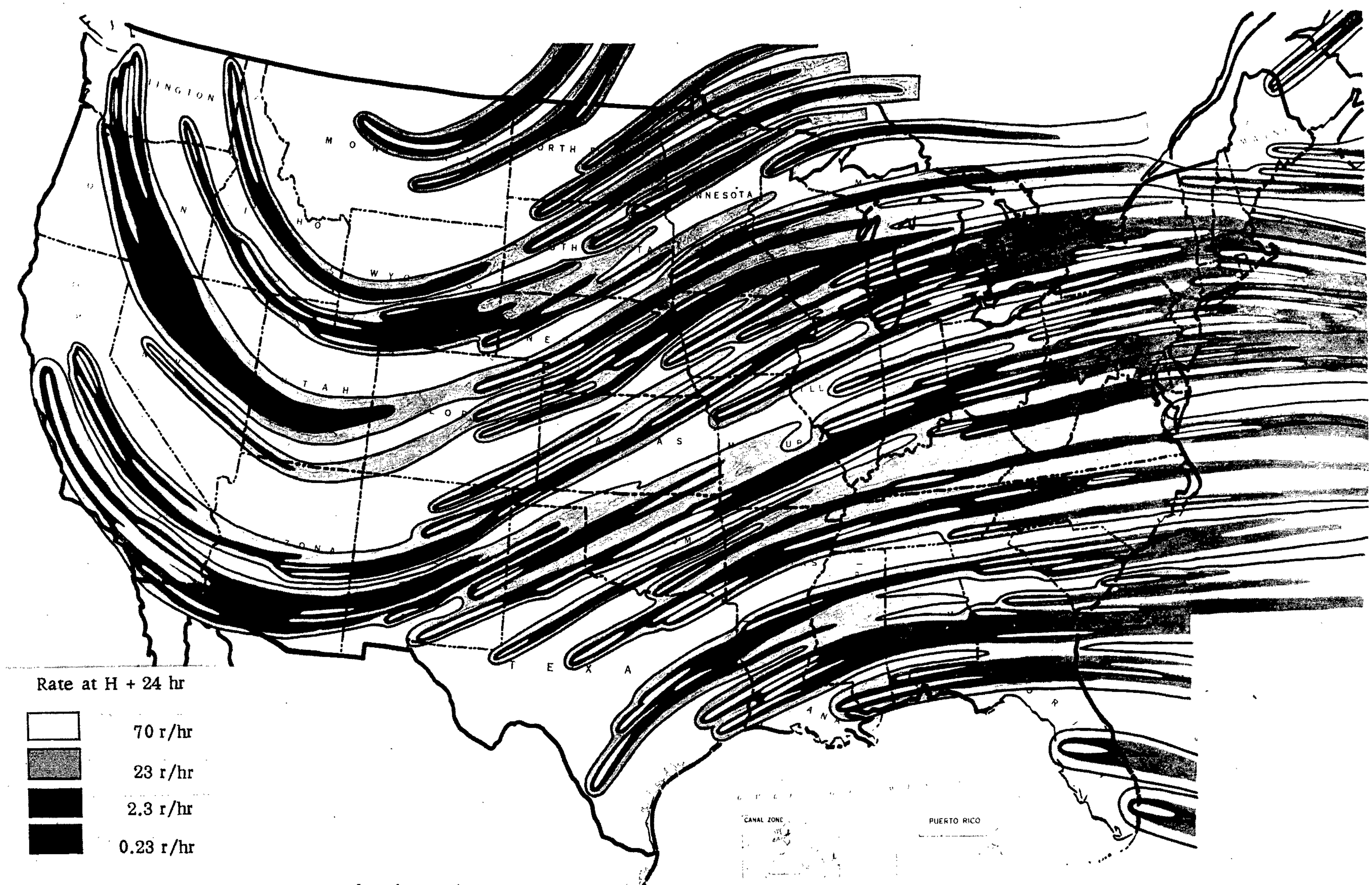

Fig. 1—Fallout conditions at 24 hr after detonation.

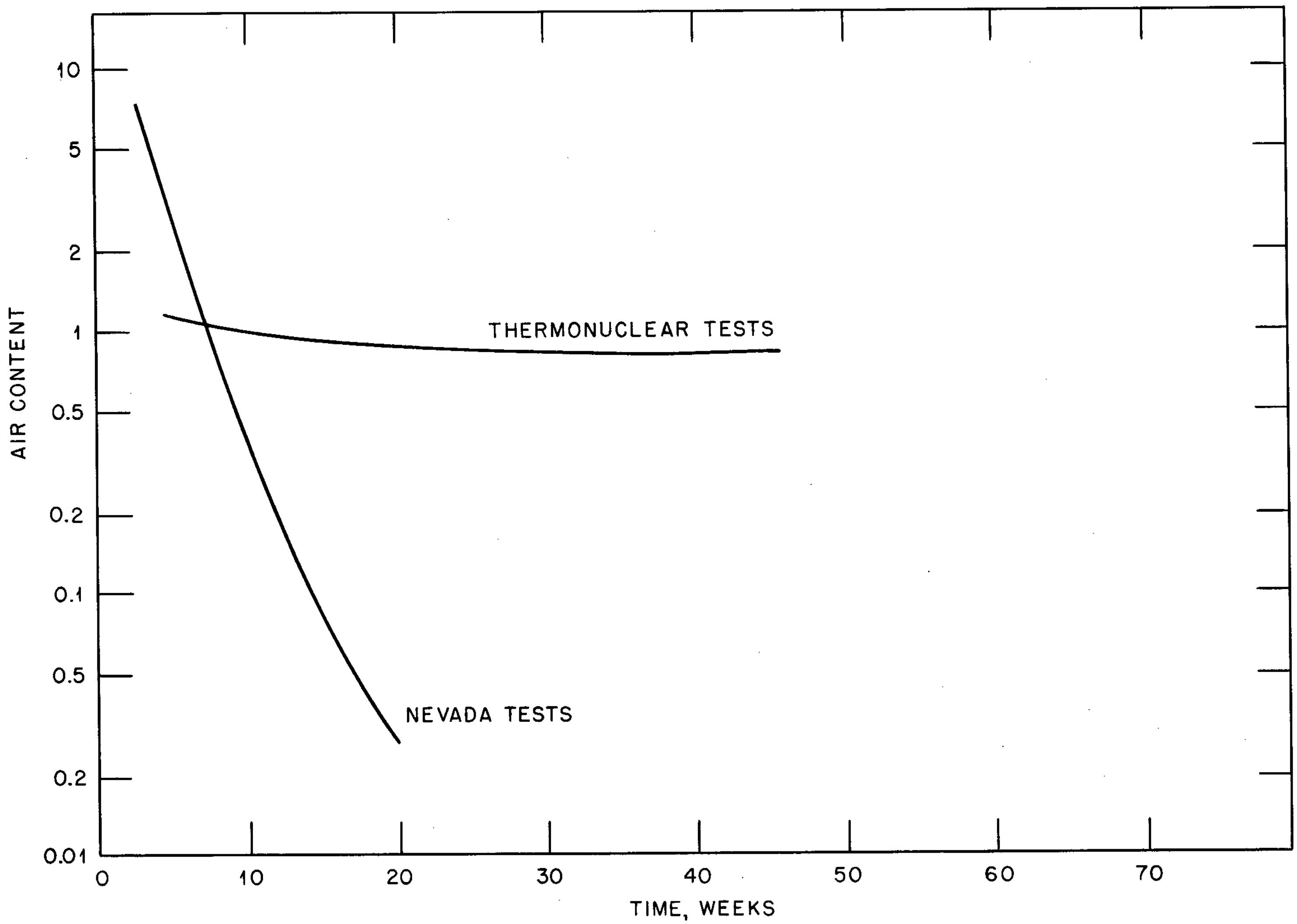

Fig. 2—Intermediate fallout from Nevada and thermonuclear tests.

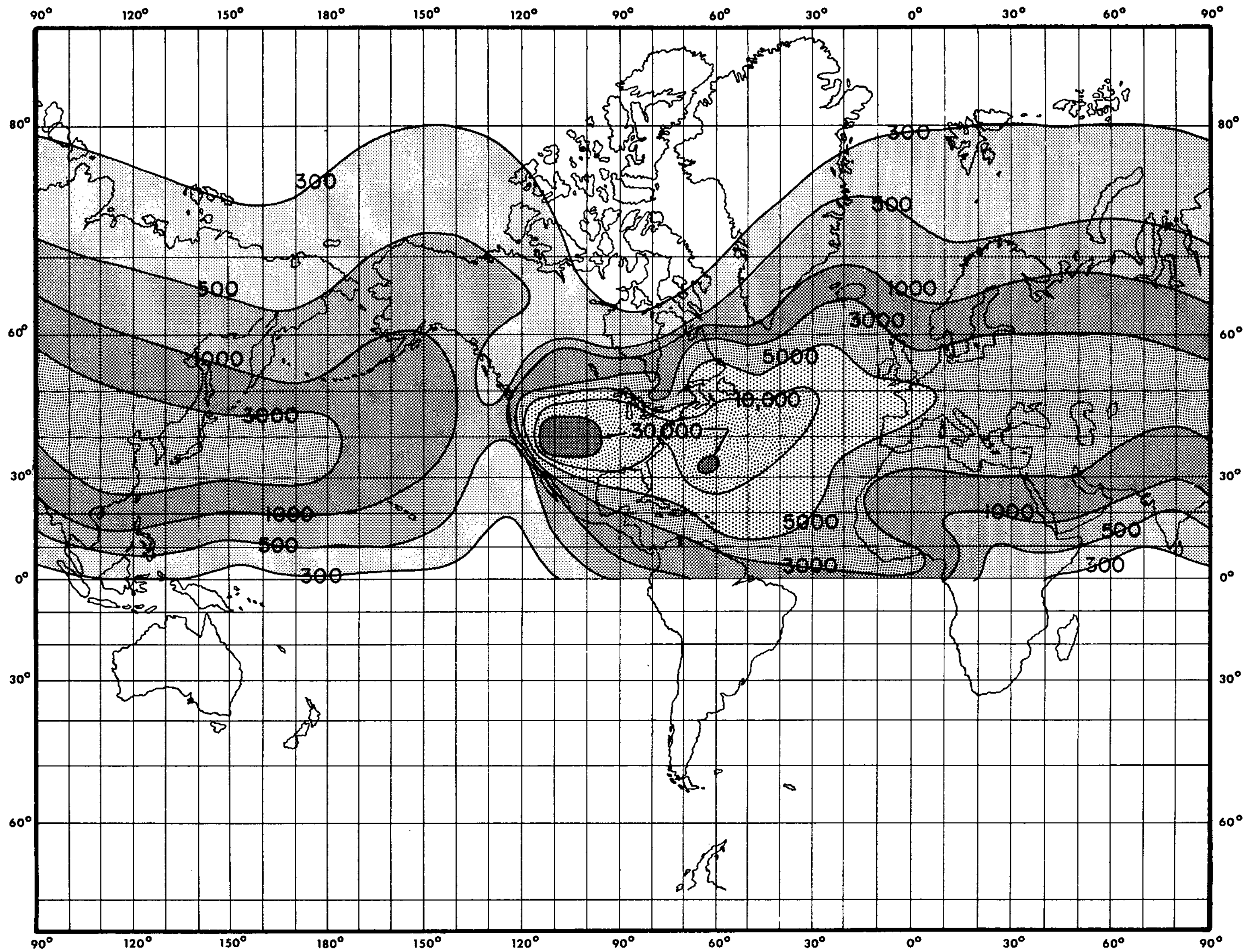

Fig. 3 — Intermediate fallout from Operation Upshot-Knothole.

be the case if the deposition were uniform over the entire globe.

Within the band of tropospheric fallout there is patchiness as well. Not only is there a general decrease downwind and in a north or south direction from the source but also variations which depend on rainfall. Thus outside of the first, say, 600 miles from Nevada Test Site, one does not find the highest individual deposition immediately beyond 600 miles but rather in the Albany-Troy region of New York State about 2000 miles away. Here, a rapidly moving nuclear cloud at 40,000 ft was scavenged by an intense thunderstorm. The probability of a second such coincidence in the same place is, of course, very small.

We find that precipitation scavenging is the main mechanism for the deposition of small particles. The ratio of deposition in rain to that in nonrain varies from 2 to 20.

Rapid deposition in a matter of 30 to 60 days of intermediate fallout allows some of the shorter-lived isotopes to contribute to the hazard, whereas the delayed fallout, taking years to come down, involves potential hazard from only those fission products whose half lives are of the order of years. It is also worthwhile to note that the intermediate fallout is all deposited, whereas much of the delayed fallout still, literally, hangs over our heads.

4 DELAYED FALLOUT

Delayed fallout is of interest because it represents widespread deposition of a very sizeable amount of the fission products. In megaton explosion it contributes about 15 to 20 per cent for land shots and over 95 per cent for air bursts of the total fission yield. This fallout originates exclusively from particles that were initially injected into the stratosphere.

Perhaps a word of explanation about the use of the terms troposphere and stratosphere is in order. In 1899 Teisserenc de Bort first flew a balloon to high altitudes. His ascent probably looked like that on the left-hand side of Fig. 4. The temperature first decreased with altitude and then abruptly remained constant or increased with height. The point of discontinuity in the

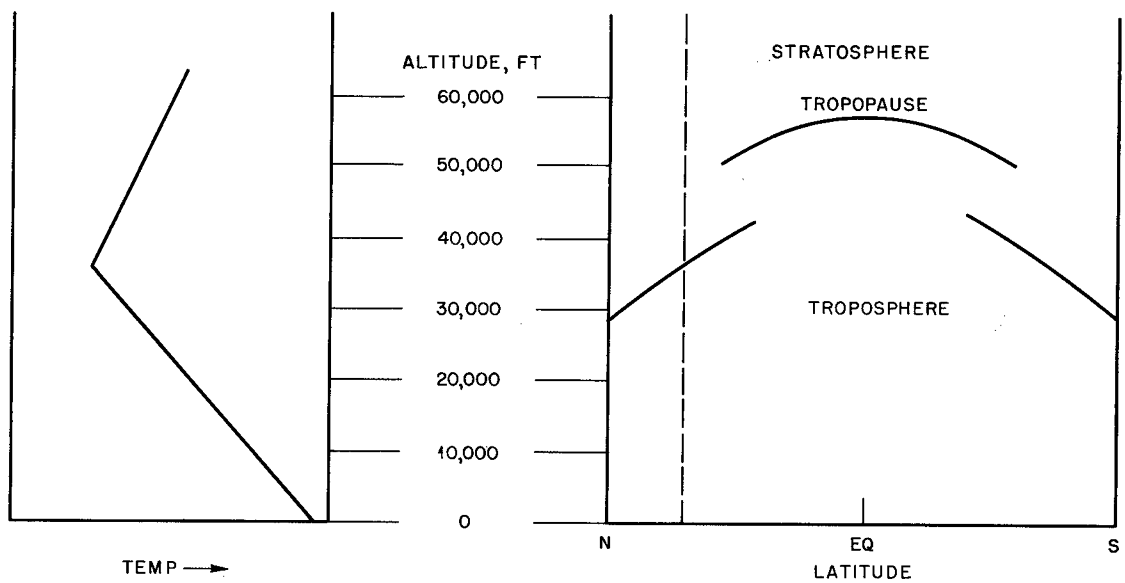

Figure 4

vertical temperature gradient is now called the tropopause and separates the troposphere below from the stratosphere above. Many of you have seen smoke emitted from a stack on a windy afternoon. It clearly reflects the turbulent nature of the atmosphere for the case of temperature decreasing with height, typical of the troposphere. On the other hand, you have also seen smoke during quieter, nonsunny periods (evenings, for example), when, near the ground, the temperature increases with height. This nonturbulent evening-like condition, we think, typifies the stratosphere. We are fairly sure that a pollutant near the ground will mix throughout the vertical extent of the troposphere in a matter of days with a few exceptions. It is suspected that the vertical mixing of the stratosphere is very much slower, being similar to the near-laminar evening mixing. Contrary to the views of some nonmeteorologists, the prolonged suspension of contaminants in the stratosphere is due to the slowness of vertical mixing throughout the lower stratosphere and not because the tropopause is some kind of a semi-permeable barrier.

The right-hand side of Fig. 4 shows the change of the tropopause height with latitude. It is highest in the equatorial region, lowest in the polar regions, and, on many occasions, shows a break in the temperate latitudes coinciding with the jet stream (a rapid west to east river of air in the upper troposphere). Less is known about the stratosphere than the troposphere, mainly because it is harder to get at. Certain evidence of atmospheric motions on transport phenomena in the stratosphere which bear on the question should be reviewed. Where should the stratospheric radioactive particles reenter the troposphere? The residence time in the stratosphere is also of concern, but, since our interest revolves around Sr^{90} or Cs^{137}, both with 28-year half lives, no significant decay will occur in the stratosphere if the residence time is much less than 28 years—which appears to be the case.

5 ATMOSPHERIC TRACERS

For more than eight years, the British have been making measurements of humidity by specially instrumented aircraft to about 48,000 ft or about 13,000 ft into the stratosphere.[5] These flights show, as seen on the left-hand side in Fig. 5, a frost point as low as 190° absolute over England. They find that this low value is amazingly constant in time. A flight in the stratosphere from the Sahara Desert to Iceland confirmed the same constant low frost point.

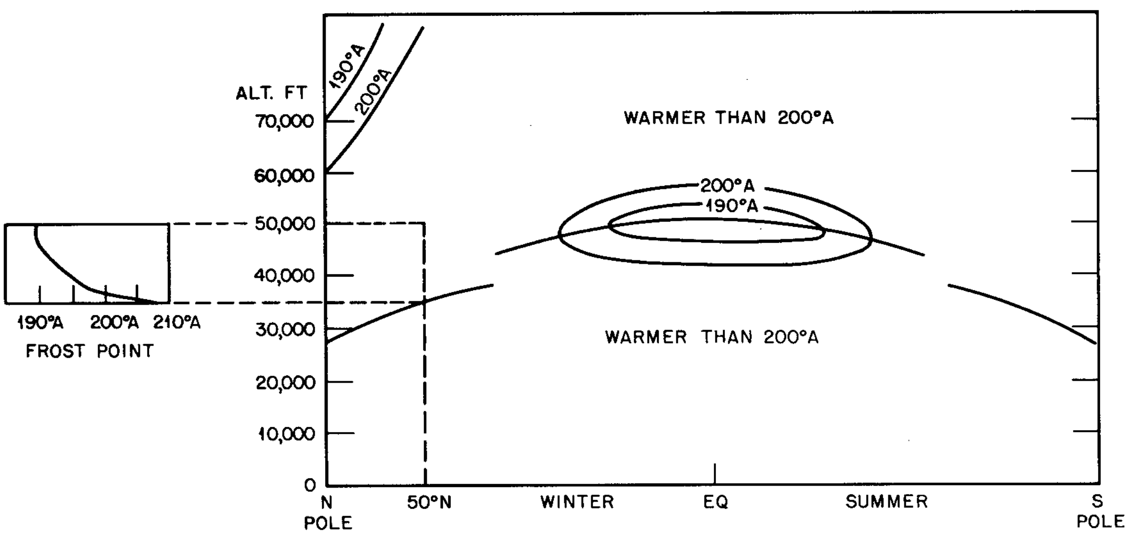

Figure 5

Where could air originate that has a frost point as cold as 190° absolute? To attain this low value, the air must have passed through a region with temperatures this cold in order to condense out the excess moisture. The most likely place, as can be seen from the right-hand side of Fig. 5 is the upper troposphere or lower stratosphere of the equatorial region. This probably means that stratospheric air over England at, say, 45,000 ft came from the equatorial tropopause region. It also means that very little tropospheric air was probably transported upward over England since this would bring moisture with it and would raise the humidity values above that which is observed.

A second tracer of atmospheric motions is ozone. Ozone is formed by photochemical reactions at about 75,000 ft and above. It is transported into the lower stratosphere by mixing and direct air movement, so that most observations below 75,000 ft show more ozone than should be there from photochemical processes alone. Measurements made primarily in Germany and reported by Paetzold[6] (Fig. 6) and as yet unreported work of Brewer and colleagues in England reflect the same seasonal variation in ozone between the tropopause at about 75,000 ft. Between 60,000 and 75,000 ft there is an ozone maximum in late winter and a minimum in late summer. In the 30,000- to 45,000-ft layer, as well as in the troposphere, the

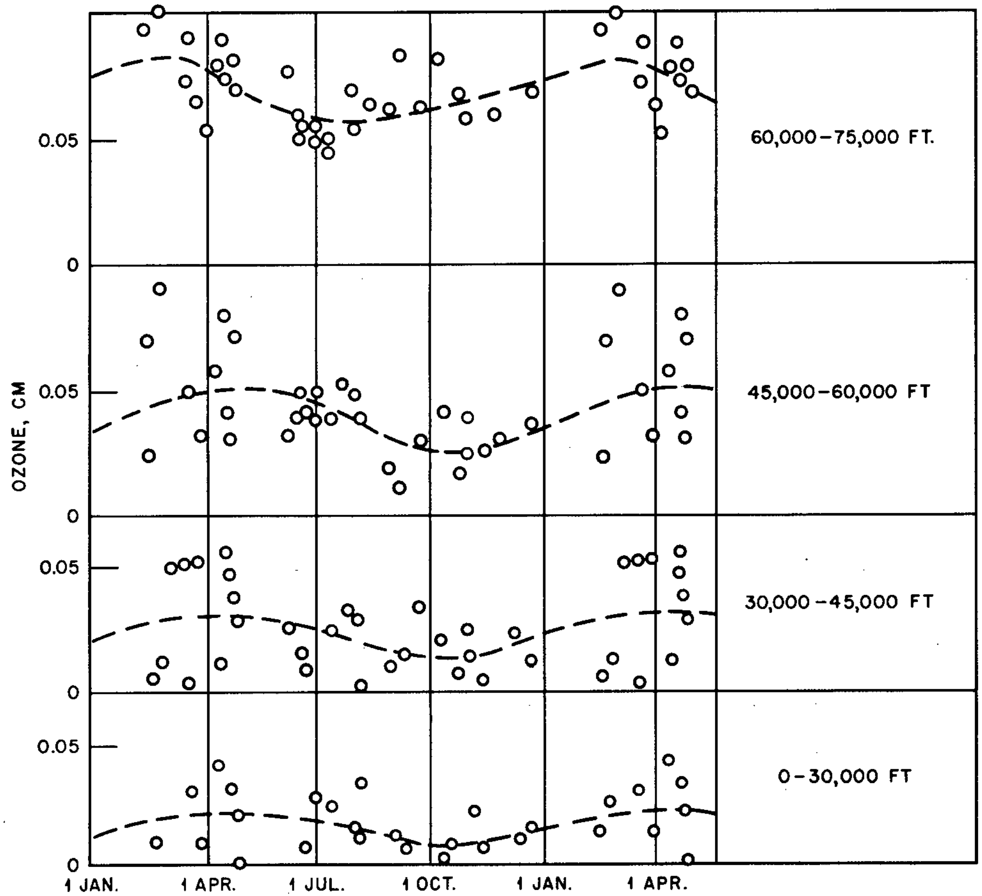

Fig. 6—Ozone, Weisenau, Germany.

maximum is in the spring and minimum in autumn. Many meteorologists ascribe the winter and spring maximum mainly to sinking motion. Thus ozone measurements can be interpreted as follows: the stratosphere of the temperate and probably the polar latitudes contain an ozone maximum in the winter or spring due to sinking motions in the winter; this ozone then empties into the troposphere; therefore by the early autumn there is a minimum.

The final bit of evidence that provides a clue to air motions is the short- and long-wave radiation balance in the stratosphere.[7] It is well known that there is a net heating in the troposphere in the equatorial regions, whereas the polar regions have a deficit. This drives our atmospheric engine. The exact mechanism by which the exchange of heat occurs is not completely known. A certain amount is exchanged by mixing processes, but some is probably carried by direct circulation in which there is equatorward flow near the ground and poleward flow aloft. Firm evidence for this cell is limited to the tropical trade winds. Since the same areas are heated and cooled in both the troposphere and stratosphere, the stratosphere may participate in this cell. In such a picture, all of the equatorward motion takes place in the lower troposphere, but a small part of the circulation may move poleward in the lower stratosphere. If this is so, there should also be a seasonal variation in the poleward stratospheric circulation since the radiation balance data indicate that the greatest net loss of heat occurs during the polar winter.

The picture based on humidity, ozone, and heat budget is summarized by Fig. 7. This particular version was taken from a paper by Dr. N. G. Stewart and his colleagues of the U. K.[8] and shows, as Brewer argues, that the air leaves the stratosphere only in the temperate or polar regions. (Reference 8 is included in Part 4 of this report as the second paper.) Those of us who propose this picture readily admit that the actual state of affairs is undoubtedly much more complex than shown here and that some mixing is superimposed on the direct circulation.

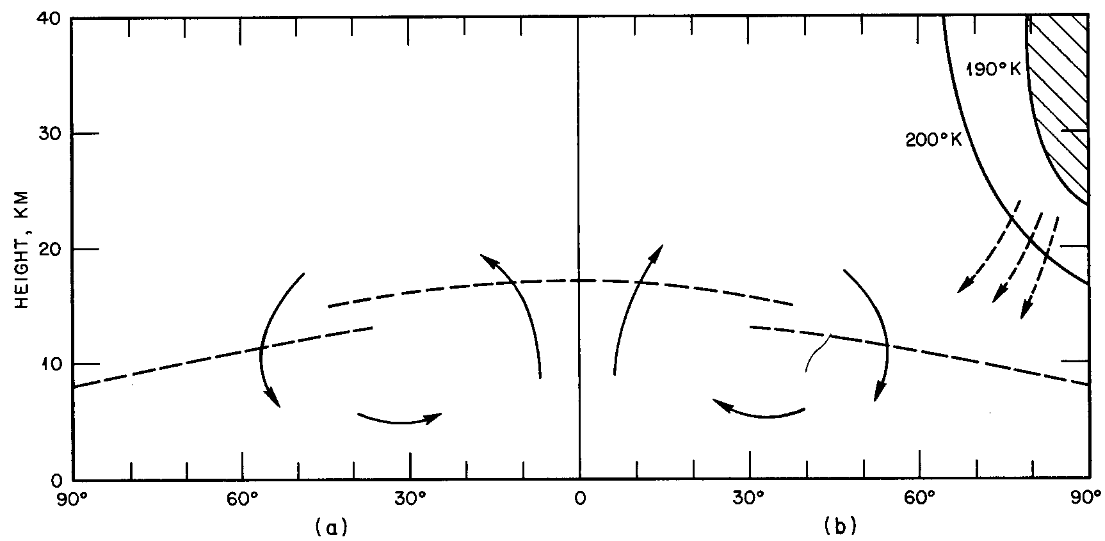

Fig. 7—Atmospheric circulation model (after Dobson and Brewer). a. Summer. b. Winter.

6 OBJECTIONS

There are two serious objections to this model: First, air that rises into the stratosphere must undergo a marked heating. This can be shown on the left side in Fig. 8. If a parcel of dry air rises and expands without gain or loss of heat from its surroundings, temperature will cool along the dashed line called the "dry adiabatic." When it rises 1 km or 3200 ft, it will have cooled owing to expansion by 10°C. The solid curve shows the observed stratospheric temperature increase with altitude in equatorial stations. This observed picture is exceedingly persistent day after day. The rising parcel must gain heat presumably by short-wave solar and long-wave terrestrial radiation to bring the parcel's temperature back along the dotted curve to the observed curve. Two objections to this process may be noted: (1) If the rising motion is

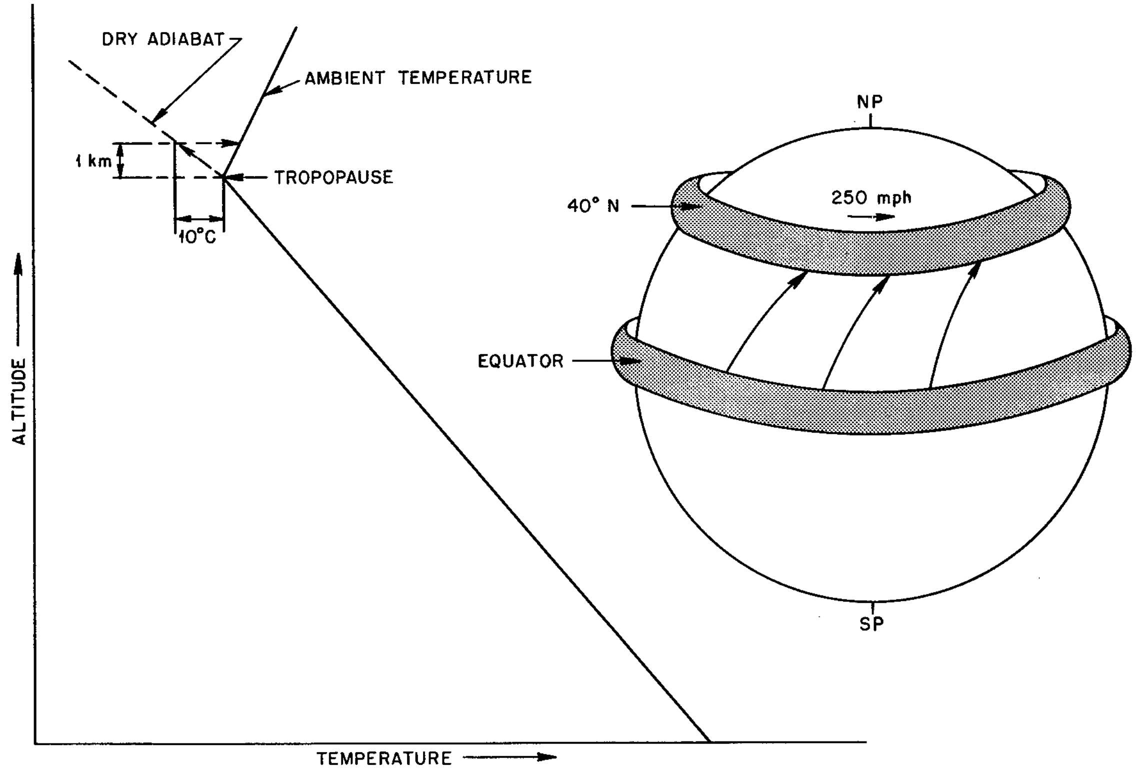

Figure 8

as fast as 1 cm/sec or a half-mile per day, which is roughly what I believe necessary, then a heating of 10°C per day is needed. Present theory calls for warming of only two or three degrees centigrade per day. Second, it does seem fortuitous, but not impossible, that two diverse atmospheric processes, cooling by expansion and radiational heating should produce as good a daily balance.

A second objection is a dynamic one and is shown on the right-hand side of Fig. 8. A ring of air at the equator will, if transported poleward, maintain its absolute angular momentum. Thus, if there were no west or east wind at the equator, this ring when brought to, say 40° would rotate at a speed corresponding to a 250-mph west to east wind. These tremendous speeds are rarely if ever observed. If there is a poleward circulation, there must also be some mixing to dilute the high resulting winds. Thus not all meteorological reasoning favors the circulation model.

Let us summarize the predictions that Fig. 7 offers for the problem of the motion of stratospheric radioactive particles: the large amount of debris that originates in the Pacific Proving Grounds will be carried poleward and then be subjected to descending motion. This subsidence has its peak value in the winter and spring. As air is brought to the lower stratosphere, certain processes in the tropopause region can then carry it into the troposphere. Ordinary downward movement through the tropopause may be helped by several other special processes in the temperate and polar latitudes. The air that enters the troposphere brings radioactive particles. These are then removed from the atmosphere in a short time in much the same way as the intermediate fallout is removed. Stratospheric debris from USSR tests should, by this picture, remain in the temperate latitude, or move even further poleward, but in any case it should have a shorter stratospheric residence time. The model does not predict whether there should be greater deposition of delayed fallout in temperate or polar latitudes. Climatological statistics on precipitation would dictate more fallout in the rainier temperate latitudes, other things being equal.

7 THE OBSERVED FALLOUT

It is now proposed to compare this meteorological model with the observed distribution of fallout. Figure 9 shows a meridional cross section in which the Sr^{90} deposition per unit area in soil is plotted on a linear scale as the ordinate and sine of the latitude as the abscissa.[4a] The data show a marked peak in the temperate latitudes of the Northern Hemisphere, a minimum in the equatorial region, and a secondary and uncertain maximum in the temperate latitudes of the Southern Hemisphere. It also shows great variability among samples collected at the same latitude. Part of the variability is due to the difficulties in the analysis of the soil samples, and part is due to meteorological conditions such as raininess. Soil analyses provide the cumulative fallout since the beginning of the atomic era. Figure 10 shows the fallout in rain during a given year, 1956, by some 11 stations in the U. K.[8] and two stations in the U. S. rainfall network.[9] Again the ordinate is millicuries of Sr^{90} per unit area on a linear scale, but the abscissa is latitude on a linear scale. The same general distribution is evident. Everyone agrees that the data show more Sr^{90} deposition in temperate latitudes of the Northern Hemisphere than elsewhere in the world—a picture that would be used to recommend the reality of our meteorological model if it were not for one fact. The Sr^{90} comes not only from the stratospheric deposition but also from tropospheric fallout from the smaller tests in Nevada and in the USSR test areas, both of which are located in the temperate or polar latitudes. The critical question is: "What part of the nonuniformity is from stratospheric fallout?" Fortunately, fission-product analysis is able to shed some light on this question. Both rain water and air filters have been analyzed for shorter-lived fission products as well as the long-lived Sr^{90}. The contribution of the Sr^{90} from tropospheric fallout may therefore be assessed by finding the age of the Sr^{90}. If it can be shown that the age of the fallout is appreciably greater than 30 to 60 days, then it is very unlikely that much of the Sr^{90} could have originated from tropospheric fallout, irrespective of whether there was a recent atomic test. Several short-lived fission products, such as Sr^{89}, Ce^{141} (references 8, 10, and 11) and others, as well as dating by gross fission-product decay,[8] indicate average ages greatly in excess of 60 days. This evidence suggests that most of the fallout in the temperate latitudes must have been stratospheric fallout. The conclusion is further supported by estimates of the amount of tropospheric fallout from

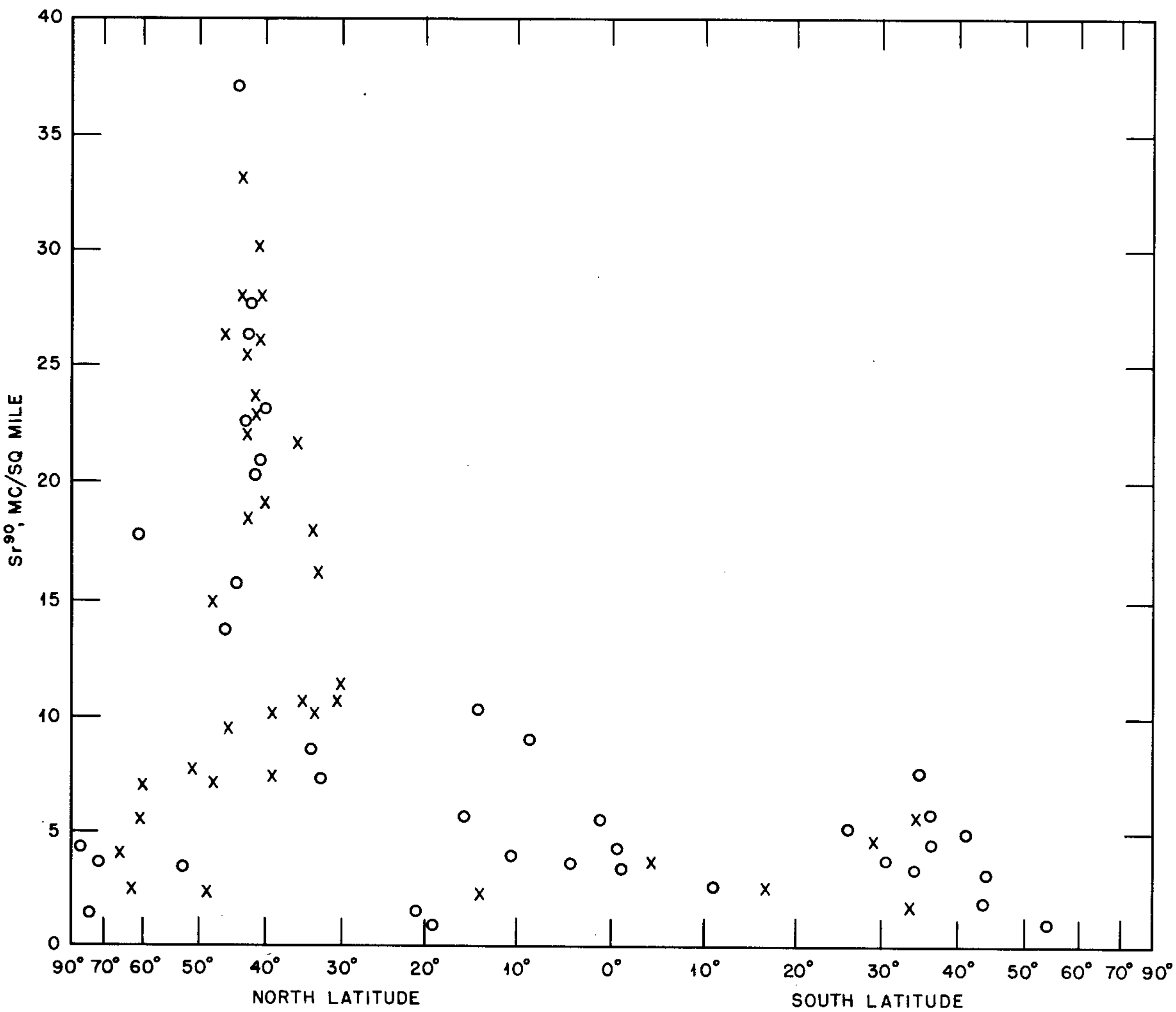

Fig. 9—Soil data, 1956: O, electroanalysis × 1.15; x, HCl extraction.

Nevada and USSR tests. Their estimated contribution amounts to a very small part of the temperate latitude bump shown by the data.[4] Other less certain arguments all add up to the same picture: the bulk of the long-lived fallout in the temperate latitudes appears to have come from the stratosphere. However, the main evidence—age determination by short-lived fission products—suffers from possible defects due to fractionation and errors in radiochemistry. New measurements are being taken of the stratospheric Sr^{90} distribution and other, and perhaps more certain, short-lived fission products to further check whether delayed fallout is uniform, or as proposed here, nonuniform over the globe. From existing evidence, it can be argued that, even if the intermediate fallout were subtracted, there would be little doubt that a marked peak of the stratospheric fallout in the temperate latitudes of the Northern Hemisphere would still appear. The polar region may show smaller values due to the smaller amount of precipitation or to the main injection into the troposphere entering the temperate rather than polar regions.

A second prediction of the meteorology calls for a seasonal variation in the Sr^{90} removal from the stratosphere with a peak in the late winter or spring. Although Fig. 11 shows the plot of 45-day fallout amounts for Milford Haven, England, in rain[8] (the solid line), similar results are found for all of the U. S. stations[9,12] that sample rain water and air concentration. The British were also able to sample and interpret air concentration of bomb radioactivity in the lower stratosphere for a short time in 1954 and 1955, the results being shown by the heavy dots. The left-hand ordinate is the concentration of Sr^{90} per unit volume of rain water rather than deposition per unit area. A plot of deposition per unit area shows just about the same picture, indicating that the seasonal variation in deposition is not due to the fact that it rains

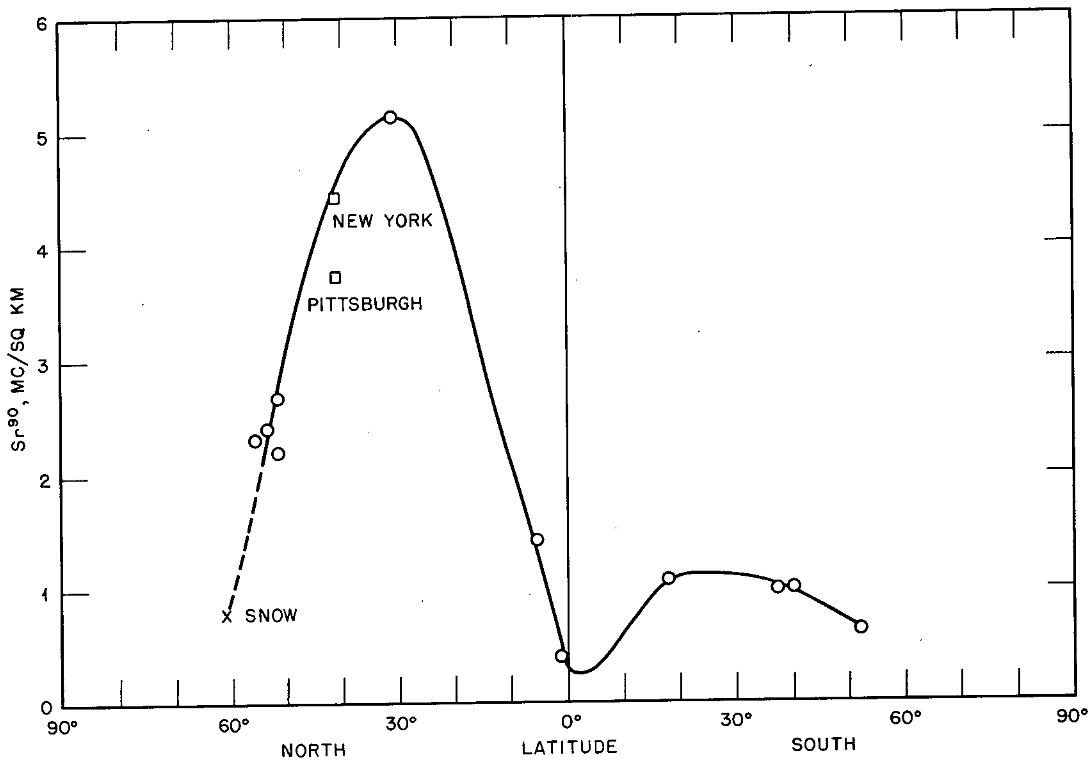

Fig. 10—Total deposition of Sr^{90} in 1956 at various latitudes.

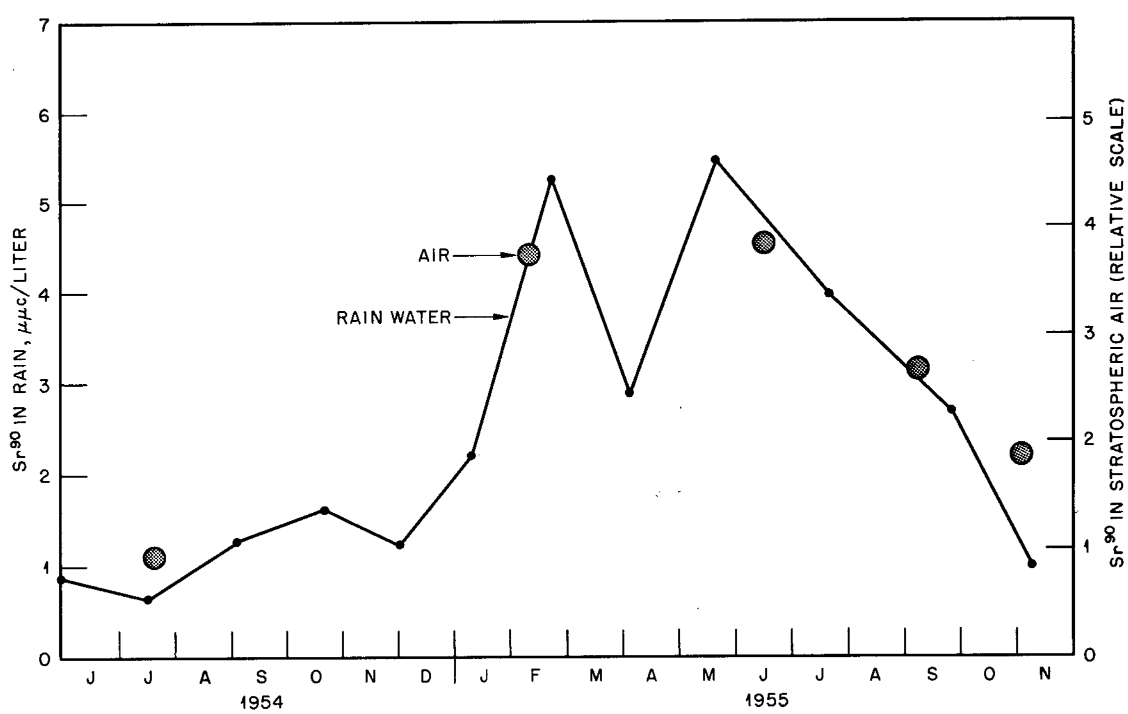

Fig. 11—Correlation between Sr^{90} concentrations in rain water and in the lower stratosphere.

more in the springtime. Figure 11 shows, in the broad view, a maximum in spring and a minimum in the autumn and is supported, more or less, for each year since 1955. The stratosphere is in phase with the deposition trends.

Figure 12 shows further seasonal variations[8] at Milford Haven, England, but adds Ohakea, New Zealand, at 40°S. Note that the peak and valley in the Southern Hemisphere station occurs during its spring and fall also, but with only a small amplitude. The Southern Hemisphere fallout is mainly that small fraction from the U. S. Pacific tests which mixed into the Southern Hemisphere stratosphere.

In addition to differences in fallout due to large-scale air motions just described, there are also variations due to anomalies in precipitation amounts. There is a large body of evidence that indicates that the Sr^{90} deposition is proportional to the amount of precipitation in a given area. Average annual precipitation plotted against cumulative deposition in soil up to about 1955 for selected sites[12] is shown in Fig. 13. The solid curve for stations in the eastern Mediterranean area shows most clearly the dependence of fallout on the amount of rainfall. The figure also shows that the greater precipitation in South America deposits less fallout, undoubtedly because the air concentration is lower.

Fallout of Sr^{90} in the United States in late 1956, as obtained from soil samples,[9] is shown in Fig. 14. The higher fallout values in the northern tier of states, relative to the southern tier, has already received considerable publicity and is not new. Among the possible explanations are errors in the soil collection or analyses. Soil analyses apparently suffer from such serious difficulties that one is led to be suspicious of results that might not follow some reasonable pattern. But these data do reflect a pattern, with perhaps the exception of the 7 mc/sq mile at Grand Junction. Further, from March through July 1956, the New York Operations Office of the AEC analyzed rain water from many stations over the U. S.[13] The results also fell into a pattern (Fig. 15) for July 1956. It is clear that stations north of 40°N yield more Sr^{90} fallout per unit of precipitation than stations to the south of 40°N. This puzzling difference in U. S. fallout is now a subject of research.

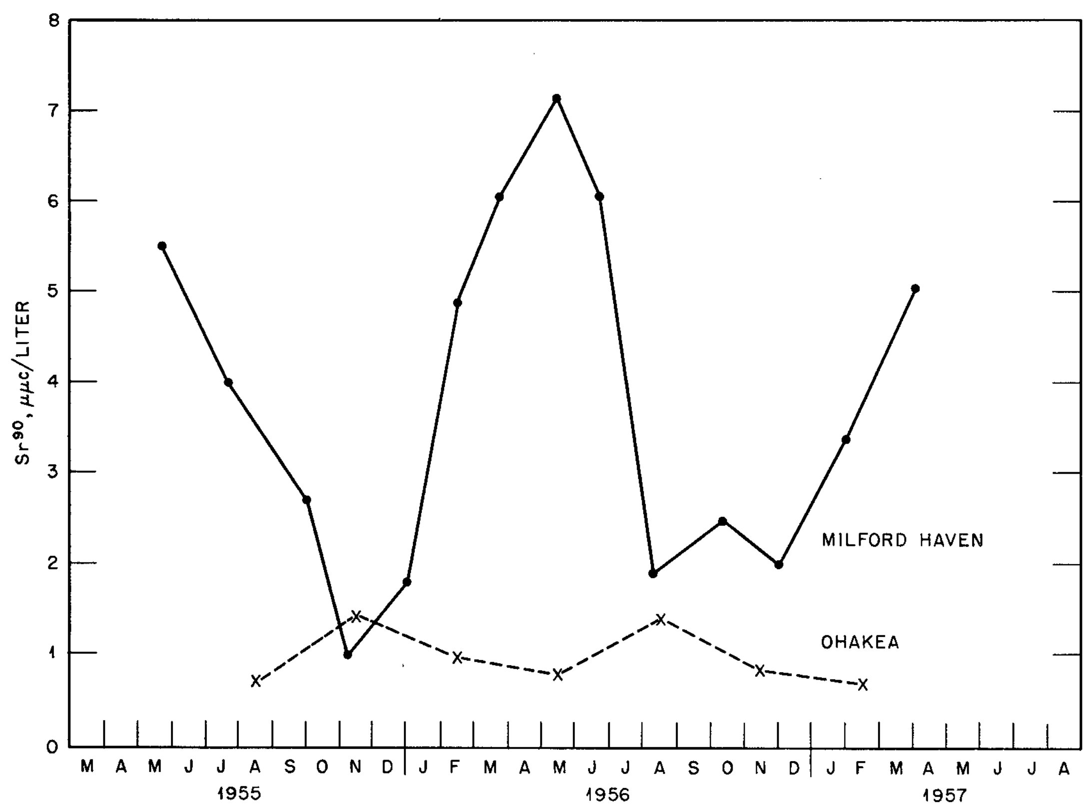

Fig. 12—Seasonal variation of Sr^{90} content in rain water at Milford Haven, England, and Ohakea.

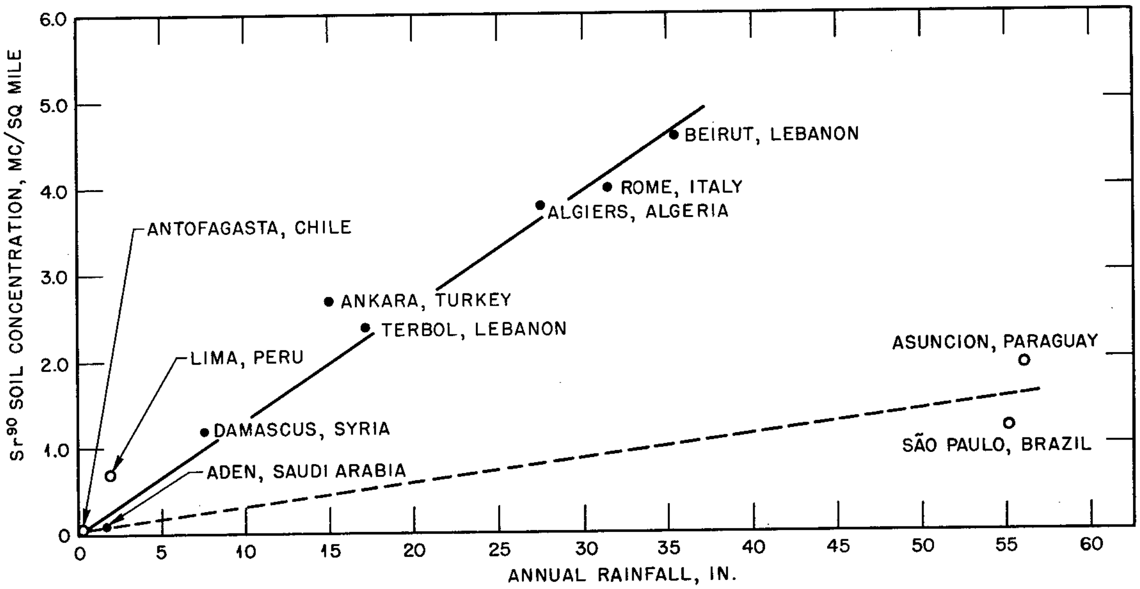

Fig. 13 — Sr^{90} soil concentration vs. annual rainfall. ———, Eastern Mediterranean area, February 1955; ----, South America, January 1956.

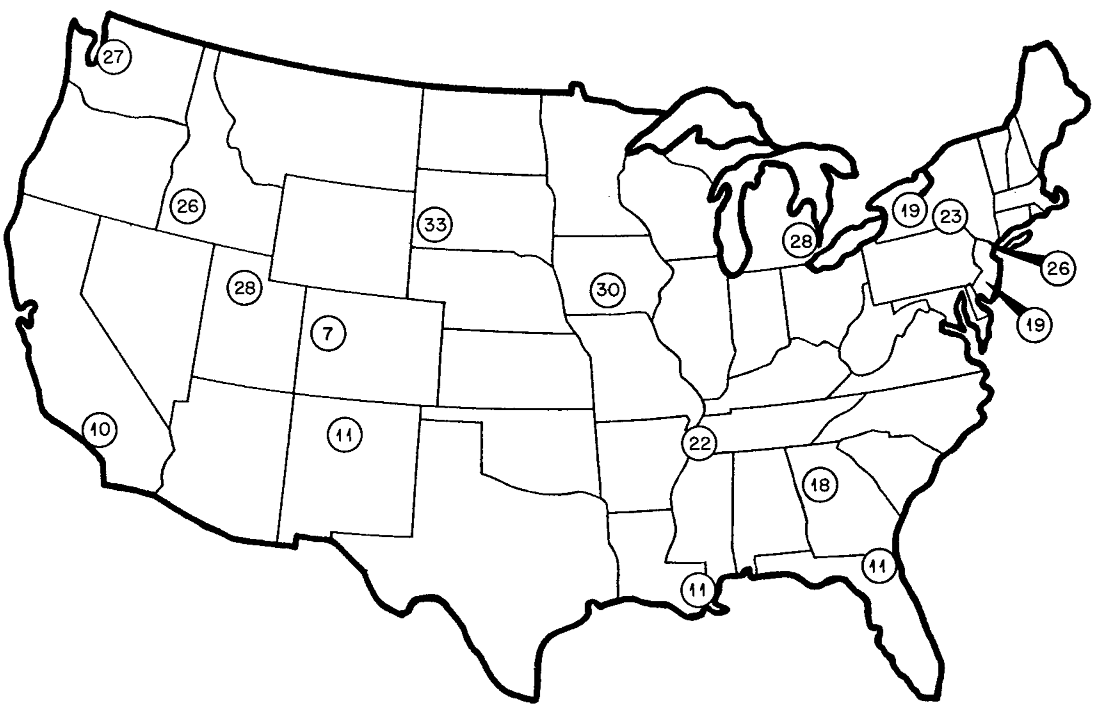

Fig. 14 — Sr^{90} in U. S. soil (HASL, Oct. 8, 1956) (HCl extraction method). Numbers are in millicuries per square mile at individual site.

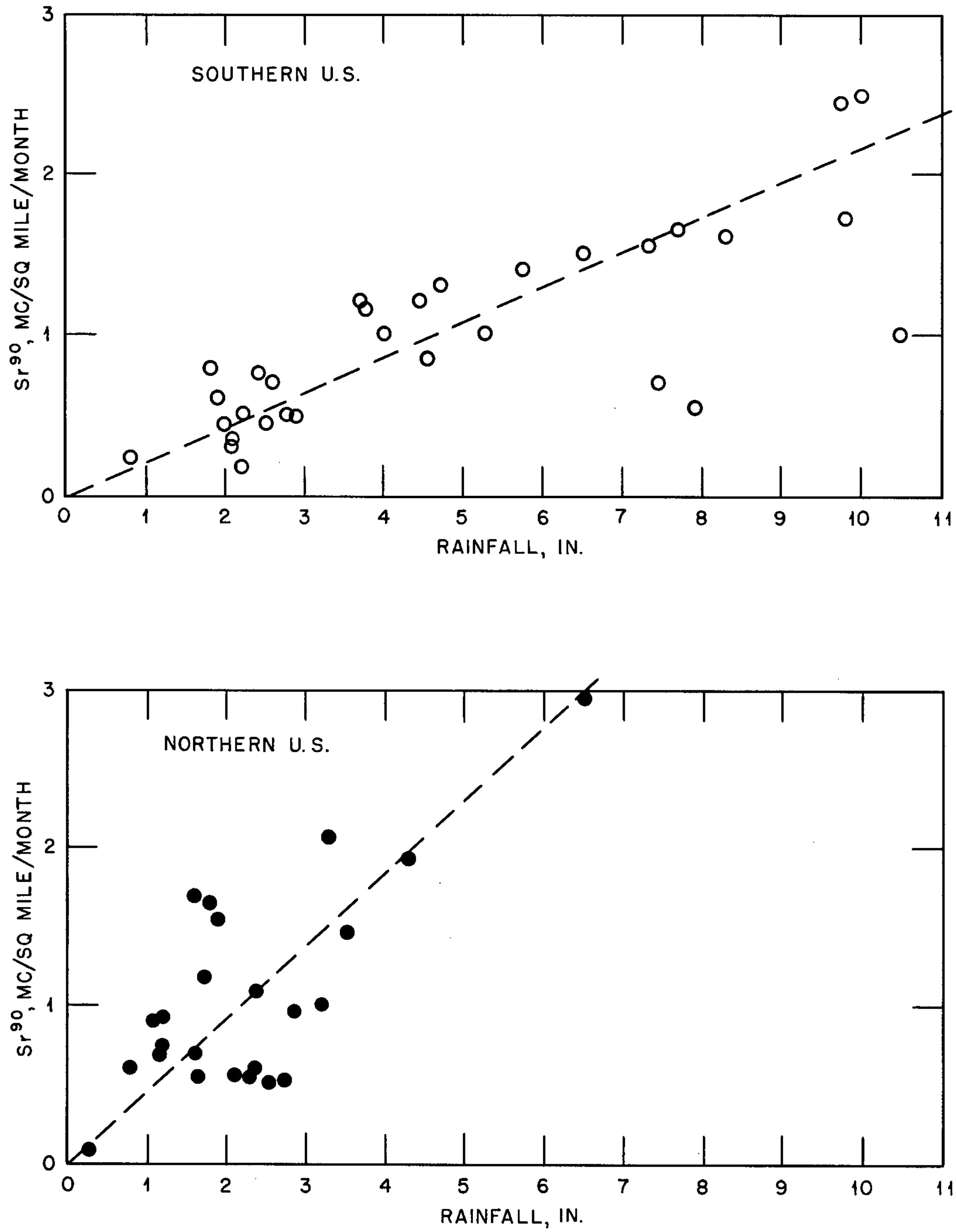
SOUTHERN U.S.
Sr^{90}, MC/SQ MILE/MONTH
RAINFALL, IN.
0
1
2
3
4
5
6
7
8
9
10
11
NORTHERN U.S.
Sr^{90}, MC/SQ MILE/MONTH
RAINFALL, IN.

Figure 15

8 CONCLUSIONS

It is thus evident that meteorological theory is involved in predicting future fallout. Such forecasts are uncertain not only because of ignorance about future testing but also because we can only guess at where the fallout will be deposited. The model described in this paper is, after all, still being developed. However, although meteorological deficiencies might appear to be large, they are smaller than the biological uncertainties described in other papers of this symposium.

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